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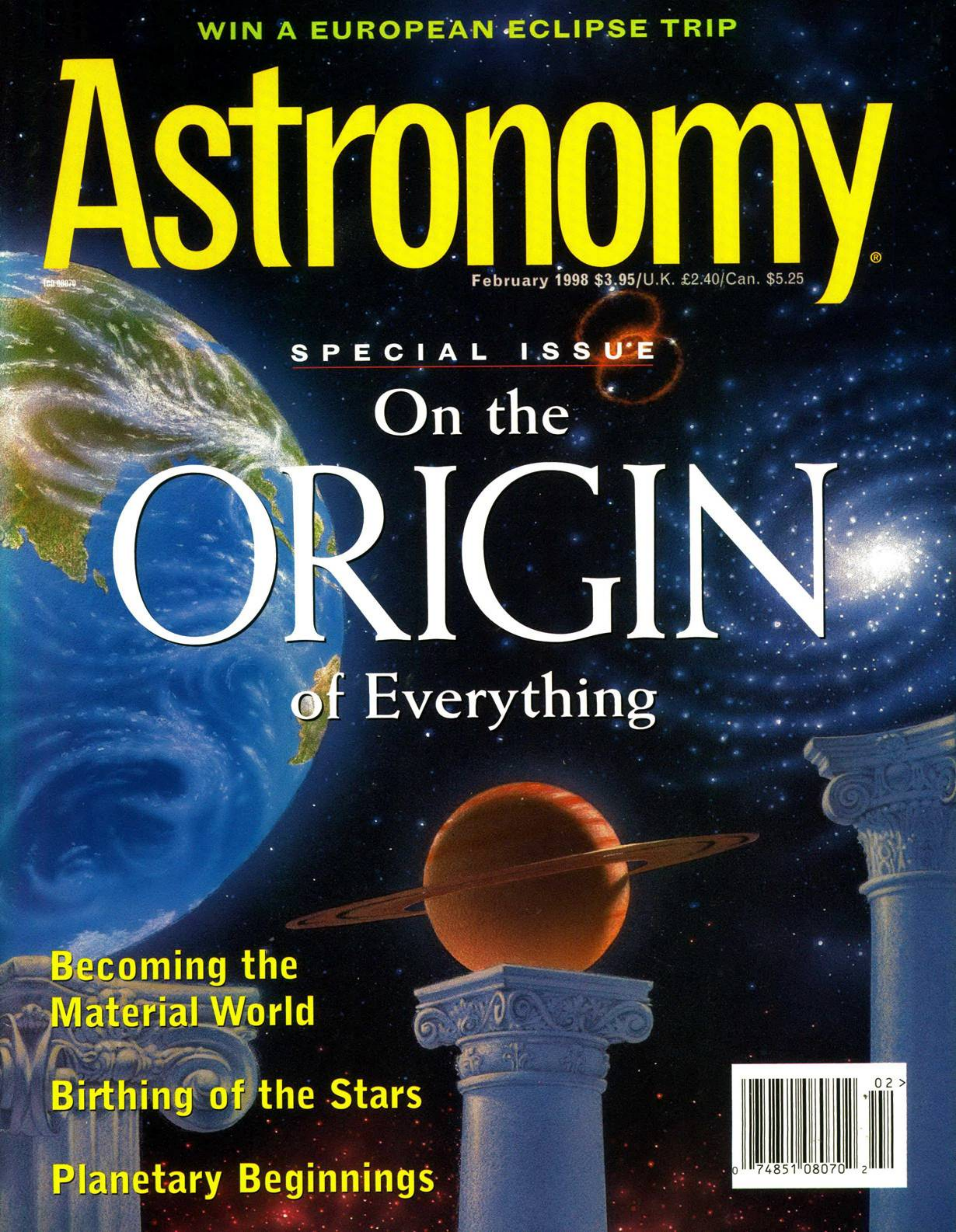

SPECIAL ISSUE

On the ORIGIN of Everything

Becoming the Material World

Birthing of the Stars

Planetary Beginnings

02 >

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LX50

Advanced technology at the most affordable prices *ever.*

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below).* A North-South switch permits telescope operation anywhere in the world.

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

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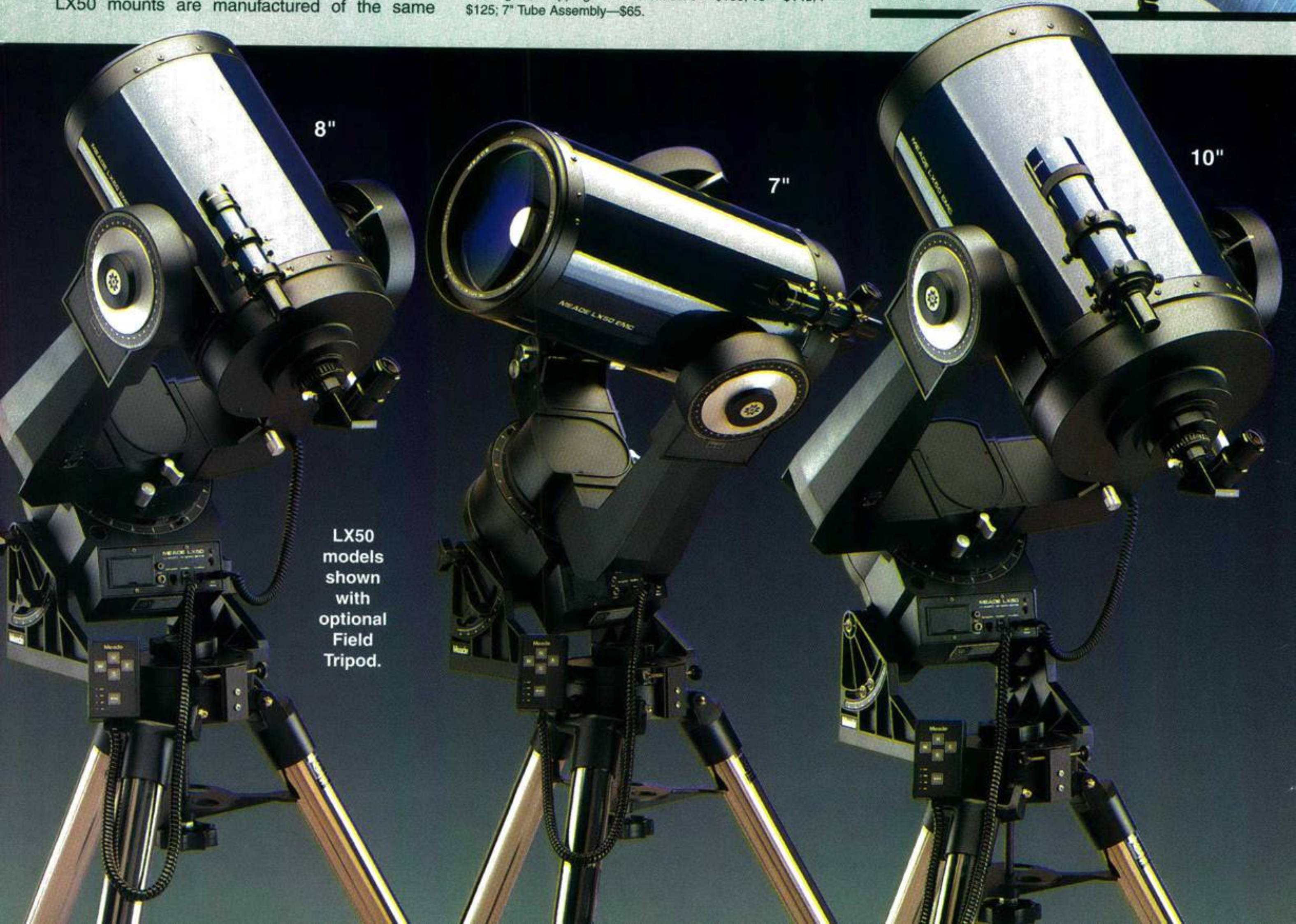
only $495!

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



LX50 models shown with optional Field Tripod.

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

■ **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.

■ **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

■ **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*

■ **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.

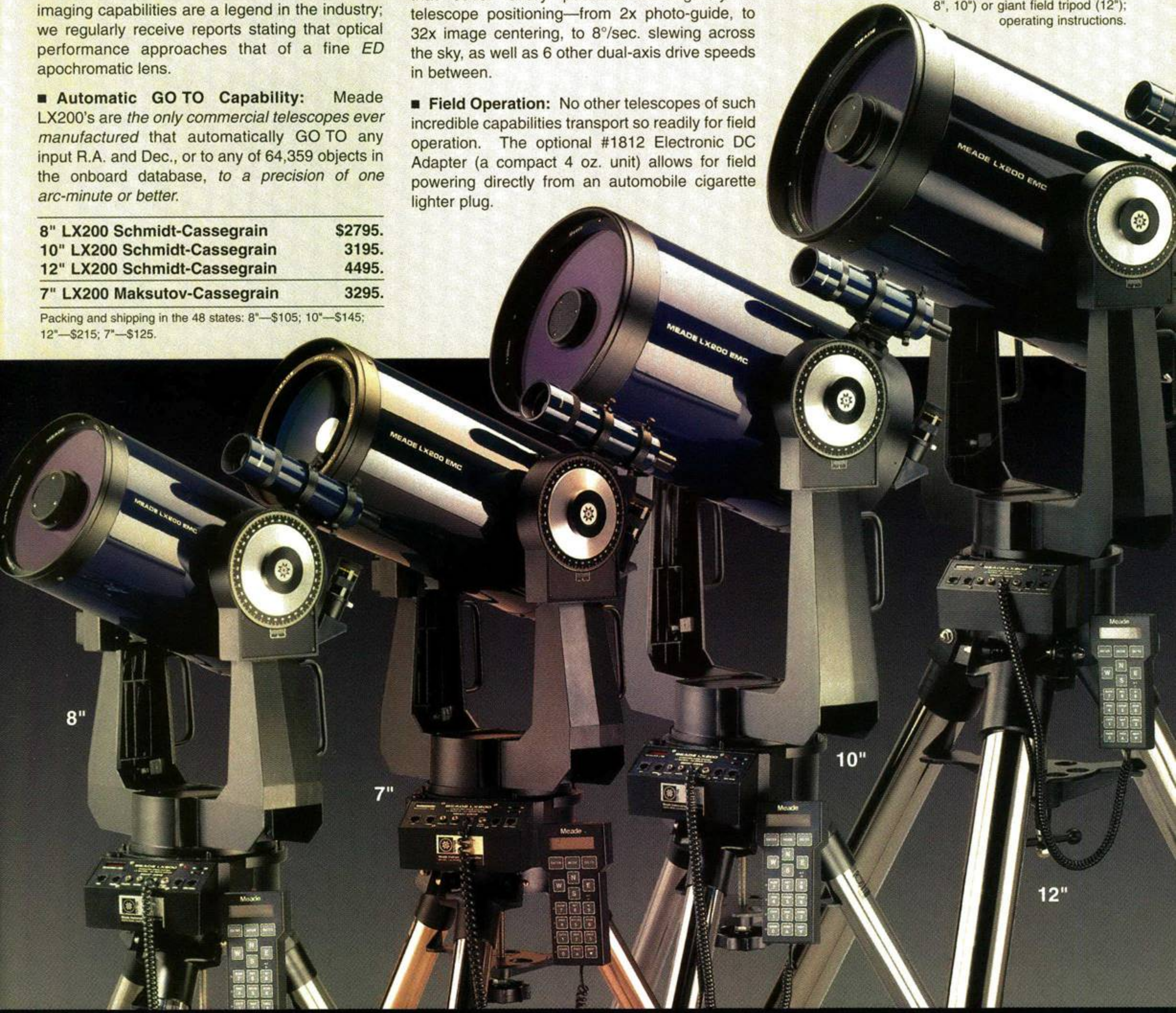
■ **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.

■ **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.



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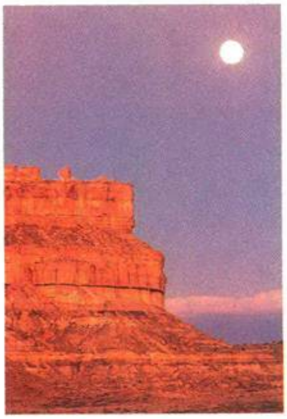
David Malin/Anglo-Australian Telescope Board



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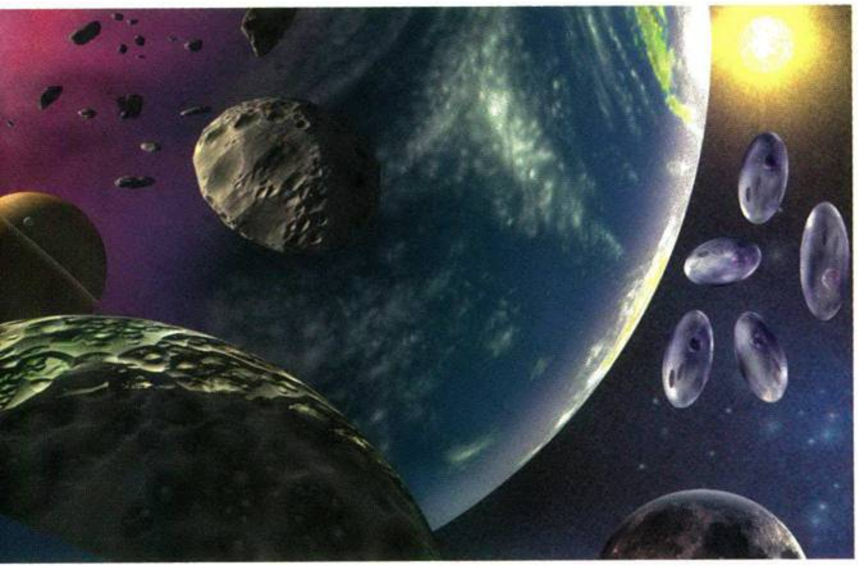

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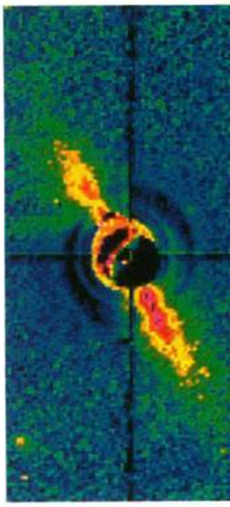

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University of Arizona/JPL

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Doug Ross

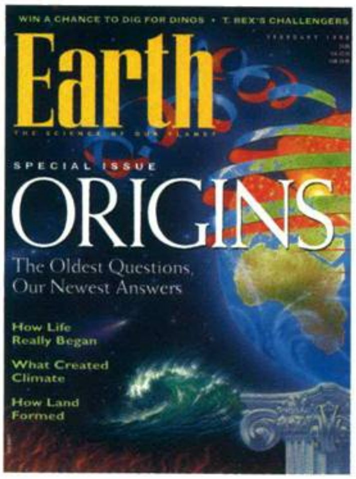
dark matter
Lithium

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

On the Origin of Covers

Every culture has a story about how it all began — Earth, sky, water, plants, animals, people. You might say that the story of how it all begins is the subject of every issue of this magazine. But this month, we are attacking the creation stories head on — and with the best scientific minds of our generation. Origins is the subject of a two-part report, the first half of which you will find in these pages, the second half in the pages of our sister publication, *Earth* magazine.


WIN A CHANCE TO DIG FOR DINOS • T. REX'S CHALLENGERS
Earth
SPECIAL ISSUE
ORIGINS
The Oldest Questions, Our Newest Answers
How Life Really Began
What Created Climate
How Land Formed

Earth: Marly Gisser, Art Director

The February 1998 "Origins" cover of *Earth* magazine was designed to resonate with our own.

A year ago, a former editor of *Earth*, Tom Yulsman, called me and suggested a series of stories on the beginnings of everything astronomical. He thought we might even consider sharing this Origins topic with *Earth*. Josh Fischman, the editor of *Earth*, it turns out, was already working on a series of Origins stories. We agreed that this would make a splendid subject for the two magazines to share. We gained the support of our editorial staffs and the marketing staff, and we began assigning stories to writers. We asked a few terrific writers to work with us, and they said yes. Most of their stories came in early and polished. The production of the stories and the inside illustrations was pretty much a breeze.

Producing the covers, well that was another matter. We thought the covers should refer to one another, so we hired the same talented artist, Matt Zumbo, to do both. The poor man was happy to accept. Little did he know how tough it would be to win consensus from two picky art directors and two very picky editors (not to mention the people in charge of newsstand sales and the publisher). We had meetings. We had conference calls. We had sketches and sketches and sketches. "What does this mean?" "Why this color?" "This is just too conceptual." A collaboration like this can take months of negotiation and compromise.

There were a few days when I thought our cover would be bare. But after hard work and minor disagreements, we got to the cover you hold in your hands, a grand result from a good idea. This is what collaborative journalism is all about. You sometimes have to debate the issues a long time when you involve many people in a decision, but the result almost always is better than it would have been if it were made by just one someone.

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial phone: (414) 796-8776; advertising: (800) 558-1544; customer service: (800) 446-5489; subscriptions: (800) 533-6644, 7 days a week, 24 hours a day; fax (414) 796-0126. Copyright © 1997 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Periodicals postage paid at Waukesha, WI, and additional offices. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription price: 1 year $34.95, Canadian and foreign: 1 year $45, payable in U.S. funds (Canadian price includes GST). BN 12271 3209 RT. Canadian International Publications Mail Products Agreement 545-775. Not responsible for unsolicited materials. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612.

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MEADE 500-Series

Experience all of the high-resolution optical performance and mechanical precision of a MEADE reflector, refractor, or Schmidt-Cassegrain, at a moderate pricing level. Each complete 500-Series model includes the all-new MEADE LXD 500 equatorial mount with dual-axis worm gears, engraved setting circles, micrometric slow-motion controls in RA and Dec, rigid aluminum tripod, and a full complement of accessories. Choose from among five models the one that's right for your budget and observing requirements. *For complete details send for your free copy of Meade Bulletin 500.* Optional systems for Meade 500-Series telescopes include:

#1701 Single-Axis RA Drive System	**$145.**
#1702 Dual-Axis Drive System, with 4-speed hand controller	**195.**
#1708 Computer Drive System, with LX200-type hand controller, 4°/second slewing, Smart Drive, and 64,359-object database.	**795.**
#812 Polar Alignment Finder	**49.**

Prices shown are suggested U.S. national mail-order retail prices.
Packing and shipping: 4" models—$55; 4.5" and 5"—$45; 8"—$65.

Shown with optional #1708 Computer Drive System

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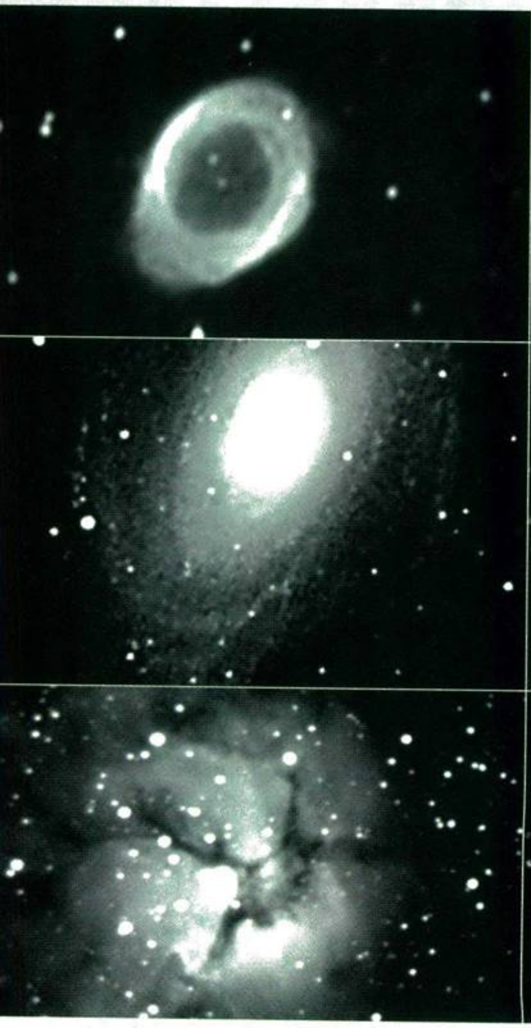
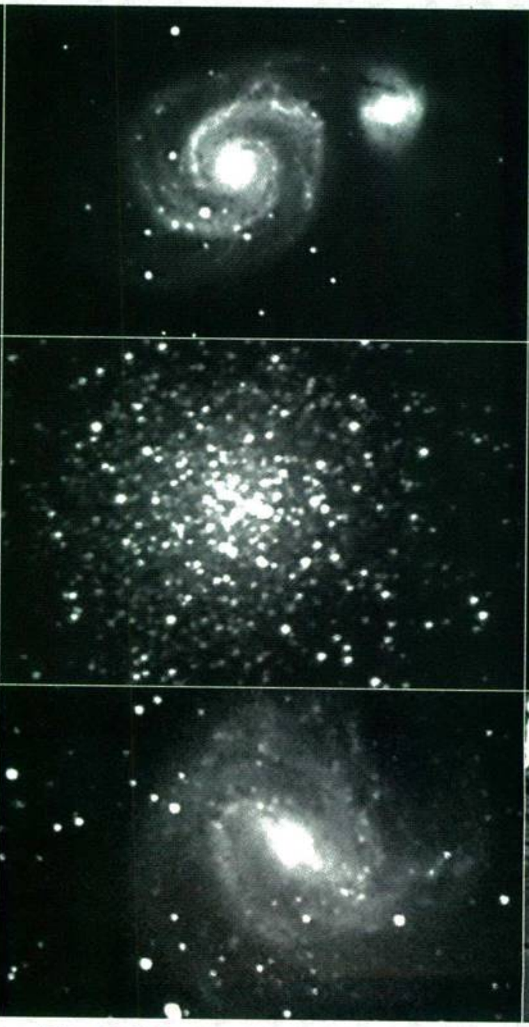
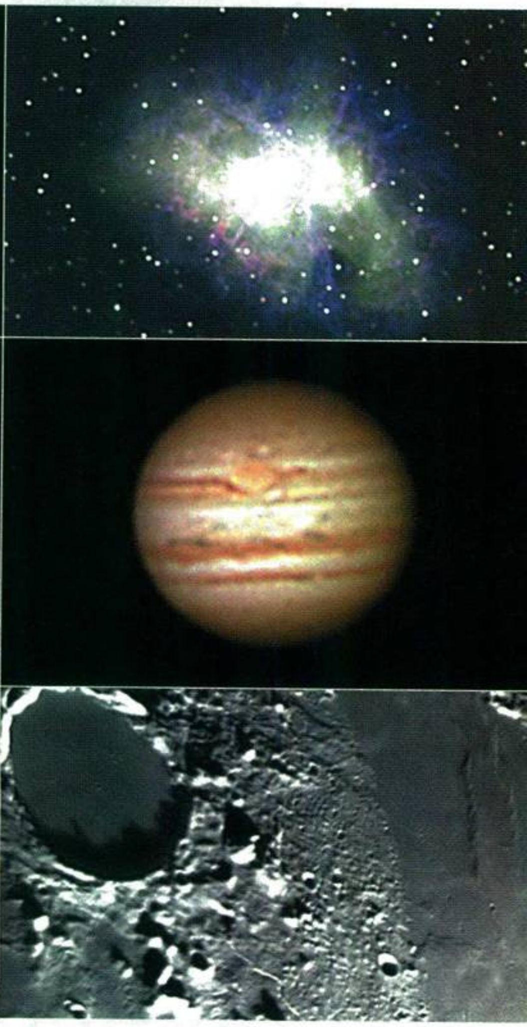
Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 100-page Meade General Catalog.***



Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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MEADE LX10 EMC
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8" LX10

All the optical performance of Meade 8" LX50 and LX200 Schmidt Cassegrains...for only *$995!*

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features* — or such a range of important options for special applications. *Standard-equipment includes:*

Super Multi-Coated Optical System: The LX10 includes the *exact same* 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.
$995. (+ $65 packing & shipping in the 48 states)

LX10 Field Tripod	**195.**
LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

The 100-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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Add the optional LX10 Declination Motor for dual-axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

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STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
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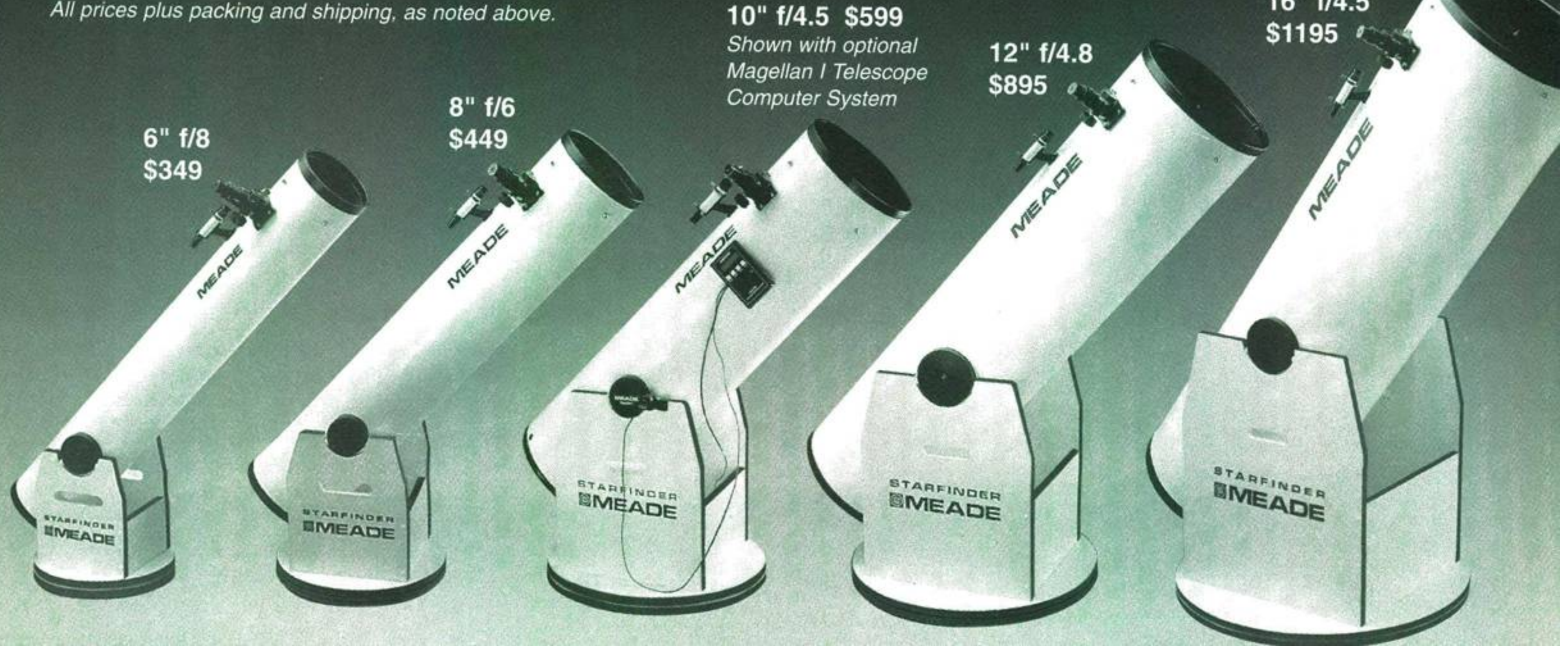
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***

All prices plus packing and shipping, as noted above.



6" f/8
$349

8" f/6
$449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE STARFINDER EQUATORIALS

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

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MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*

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Orders: 800-767-9576; Info.: 510-447-9570.

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RIVERS CAMERA, Dover, NH.
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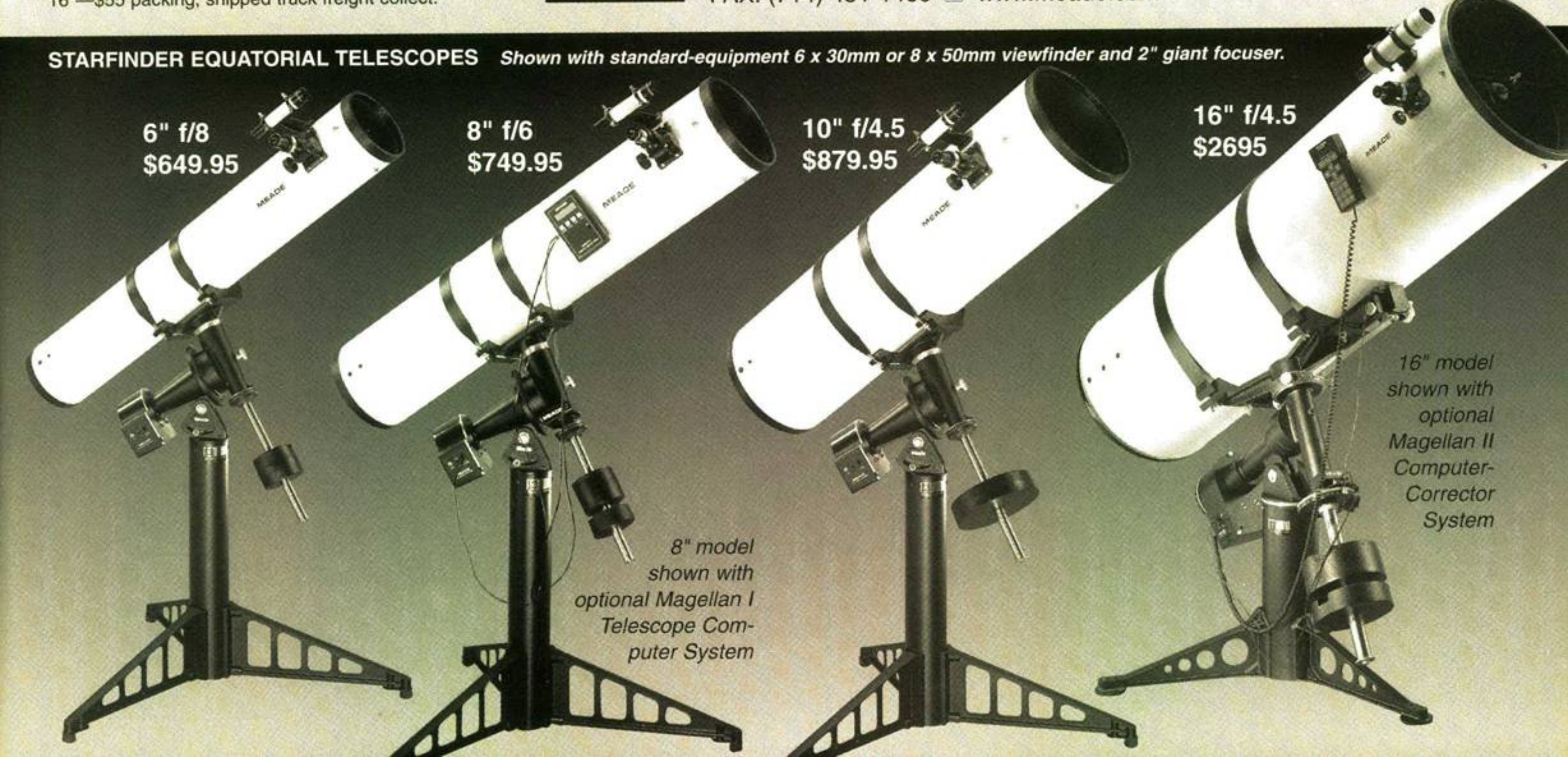
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

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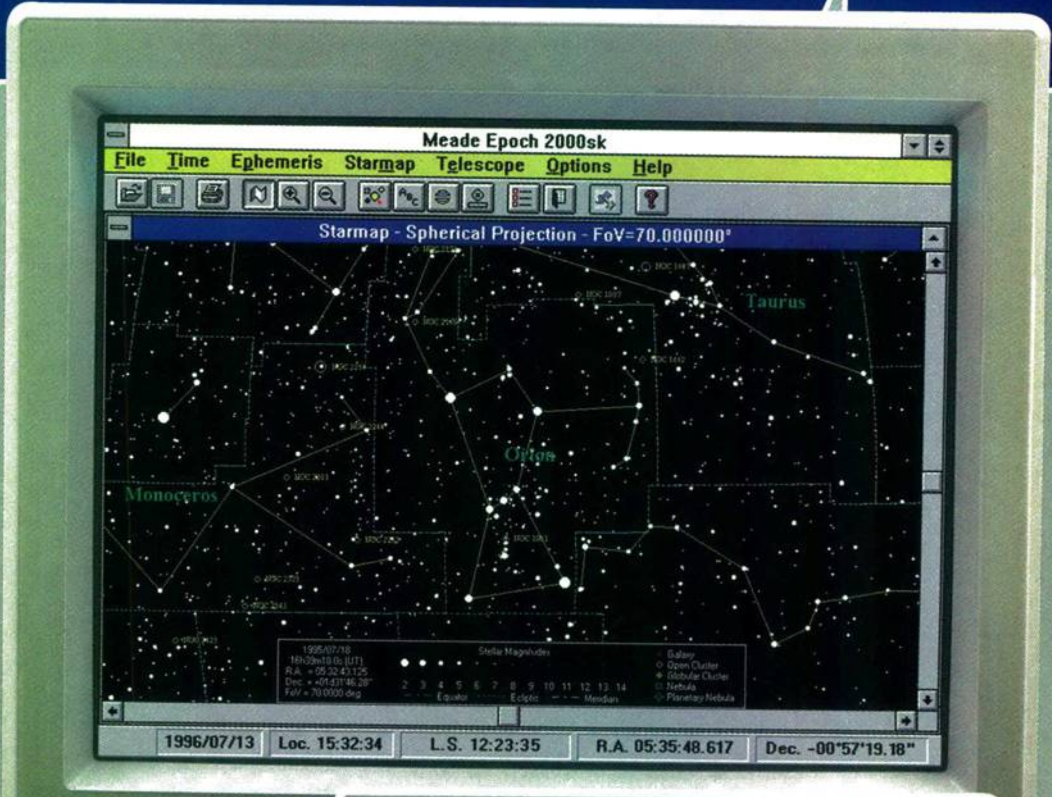
EPOCH 2000® SKY SOFTWARE

The most powerful astronomical software ever made available can now be yours for only $149!



Meade Epoch 2000sk

File
Time
Ephemeris
Starmap
Telescope
Options
Help
Starmap - Spherical Projection - FoV=70.000000°
Taurus
Orion
Monoceros
Stellar Magnitudes
2 3 4 5 6 7 8 9 10 11 12 13 14
Equator
Ecliptic
Meridian
Galaxy
Open Cluster
Globular Cluster
Nebula
Planetary Nebula

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16h39m10.0s (UT)
R.A. = 05:32:43.125
Dec. = +01:43'46.28"
FoV = 70.0000 deg

1996/07/13 | Loc. 15:32:34 | L.S. 12:23:35 | R.A. 05:35:48.617 | Dec. -00°57'19.18"

Now you can use the most advanced, most precise sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** no longer is the Trapezium in Orion, for example, shown as a single point as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professsional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Send for your free copy of the 100-page Meade General Catalog. See why, if you're serious about astronomy, Meade Epoch 2000sk is the only sky software to use!

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 **$149**

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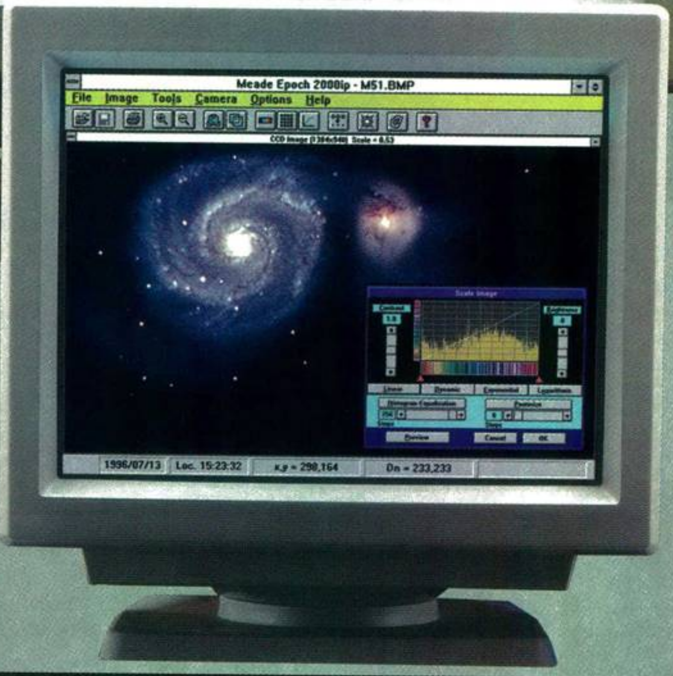
LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

Epoch 2000ip Image Processing Software: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 **$199**



Meade Epoch 2000ip - M51.BMP

File
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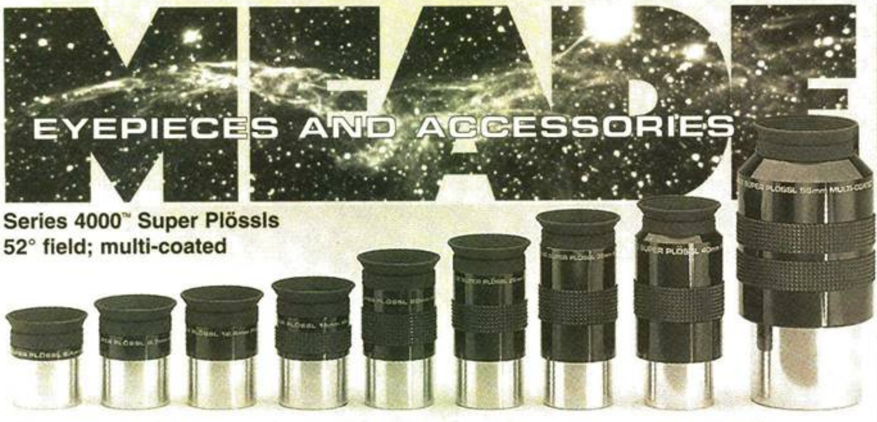


Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

World's Most Advanced Illuminated Reticle Eyepiece

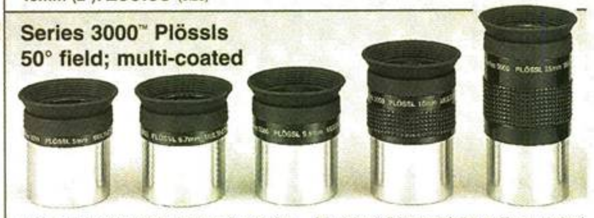
Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 3000™ Plössls 50° field; multi-coated



Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters; each eyepiece includes a fold-down rubber eyeguard for comfortable observing. Made exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters; rubber eyeguard. Apparent field: 44°.

$79.95 (3.79)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930**, each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

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Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
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POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
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KHAN SCOPE CENTRE, Toronto, Ontario.
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Looking at the Sun

I JUST READ RICHARD Talcott's article "Into the Moon's Shadow" in the November issue. I was rather surprised and disappointed that he made no mention of the 108 page bulletin I've published (with meteorologist Jay Anderson) on the 1998 total solar eclipse.

The eclipse bulletins are published through NASA in cooperation with the Working Group on Eclipses of the International Astronomical Union. The bulletins are provided as a public service to both the professional and lay communities, including educators, the media, and the general public.

There is no charge for the eclipse bulletins (your tax dollars at work). To receive a copy, readers need only send a 9" by 12" self-addressed, stamped envelope (with sufficient postage for 12 oz.). Print the eclipse date (year and month) or the NASA RP number in the lower left corner of the SASE and send it to NASA Goddard Space Flight Center, Greenbelt, MD 20771.

For readers with internet access, the eclipse bulletins are also available on the web at http://umbra.nascom.nasa.gov/eclipse/. Bulletins contain tables of predictions, maps, photographs, and weather predictions and are available for eclipses in 1994, 1995, 1997, 1998, and 1999. I also have a personal website devoted exclusively to the 1998 total solar eclipse. That address is http://planets.gsfc.nasa.gov/eclipse/TSE1998/TSE198.html. — *Fred Espenak, NASA Goddard Space Flight Center, Greenbelt, Maryland*

Berman's "Blue Sky Gazing"

I write to express my dismay at some expressions used by Bob Berman in his recent article, "Blue Sky Gazing," in the September issue regarding the use of optical aid around the sun. Though the article did contain a warning of sorts concerning using a telescope or binoculars in the vicinity of the sun, I strongly object to the glib way in which it was phrased: ". . . our attorney says we must advise you at least 17 times not to do this at all unless . . ." and ". . . whether you can turn away quickly once you've gotten an unexpected eyeful is iffy."

While it is probably true that there are a multitude of experienced amateurs out there who have heard the hackneyed intonation not to look at the sun a thousand times, have you considered the novices and young first-time (possibly last-time save for Braille) readers of the magazine who may take Berman's flippant remarks as indicating that what was said was said only for legal reasons and really isn't a problem.

There is no "iffyness" about it whatsoever. Any direct exposure of the eye to the sun via an unfiltered telescope or binoculars, even be it for an instant, is very likely to cause permanent serious damage to the retina at the least and, more likely, blindness to the eye or eyes used. I entreat you to continue to print proper solemn warnings in the future and not treat such admonitions as a subject for sarcasm. You never know, the eyesight of a young potential E. E. Barnard could be in jeopardy! — *Les Dalrymple, Sydney, Australia*

In Bob Berman's September 1997 article on daytime astronomy viewing, he wrote that welders' goggles (shade number 14) are acceptable for sun viewing. I called my opthamalogist, and she said that this may cause serious eye damage. Maybe my doctor just doesn't know what these goggles are, but I am reluctant to try this without scientific data from a physician indicating that it's safe. Where did Mr. Berman obtain his information? — *Bill Smyth, Littleton, Colorado*

Bob Berman responds: Opthalmologists, unless they also have some connection with astronomy and solar viewing, may well be ignorant of what comprises safe solar viewing equipment, and their knee-jerk reaction may be to put down everything other than some kind of "official" solar viewing material such as Mylar or the "solar skreen," originated and sold by Roger Tuthill.

Shade number 14 for welders' goggles is an extremely dense one that blocks all bandwidths, including the invisible UV and IR. Welders themselves normally use a lighter shade in their profession, such as 10 (I believe) and these wouldn't reduce the sunlight sufficiently, so this opthalmologist may simply be thinking of welders' goggles in general.

I cannot quote a particular book because so many mention it. But get hold of any reference on eclipse viewing. You could also check out my past articles in Discover *magazine (which were carefully fact checked) or talk to anyone associated with eclipses or eclipse tours. It's considered to be common knowledge.*

On a more personal note, I can attest that my students and I (hundreds of people) have personally used welders' goggles for four eclipses, and my eyesight, just tested last month, is still 20/12.

From the Peanut Gallery

I was amused by the Peanuts cartoon in the October 1997 issue ("Starstuff"), but I don't know what source Charlie Brown quoted when he claimed that no person has ever been struck by a meteorite. According to my 1984 issue of the *Teacher Brother's Almanac*, there has been at least one such recorded incident. On November 30, 1954, Mrs. E. Hulitt Hodges was hit by a three-pound stony meteorite — one that crashed through the roof of her home in Sylacouga, Alabama. She survived the encounter but was left with a severe bruise on the thigh. While the odds of a meteorite falling into someone's lap are astronomical in themselves, consider the cosmic irony of Mrs. Hodges's location — right across the street from the Comet Drive-In Theater. — *Steve Schwarz, Pinckneyville, Illinois*

(cont. on p. 17)

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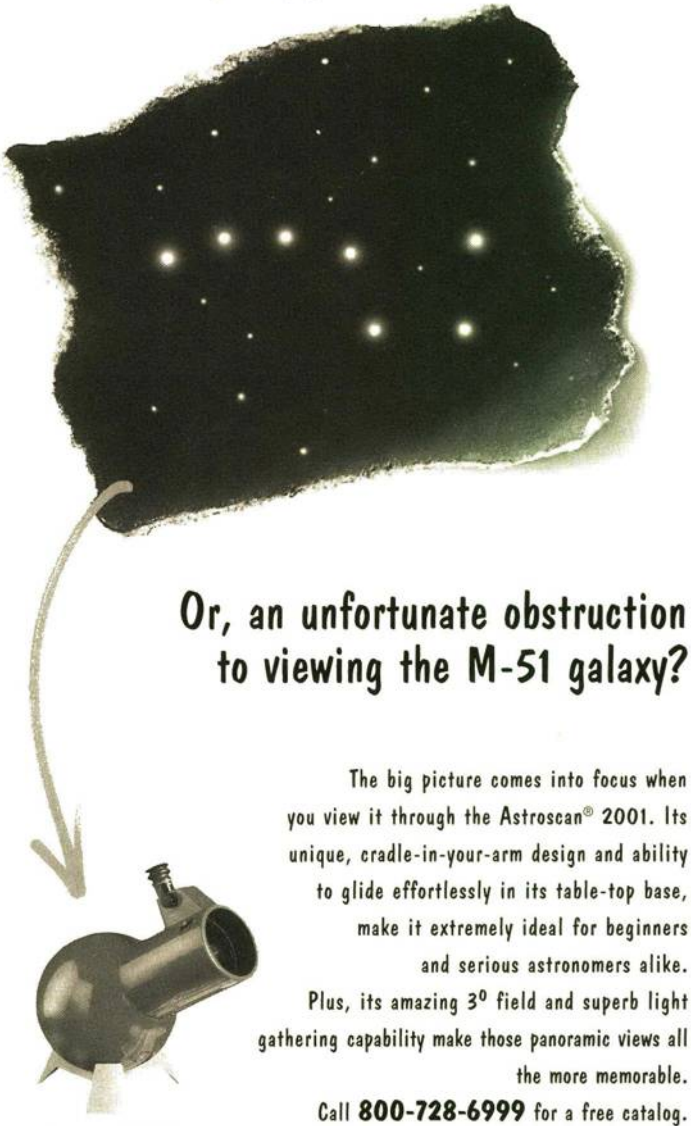

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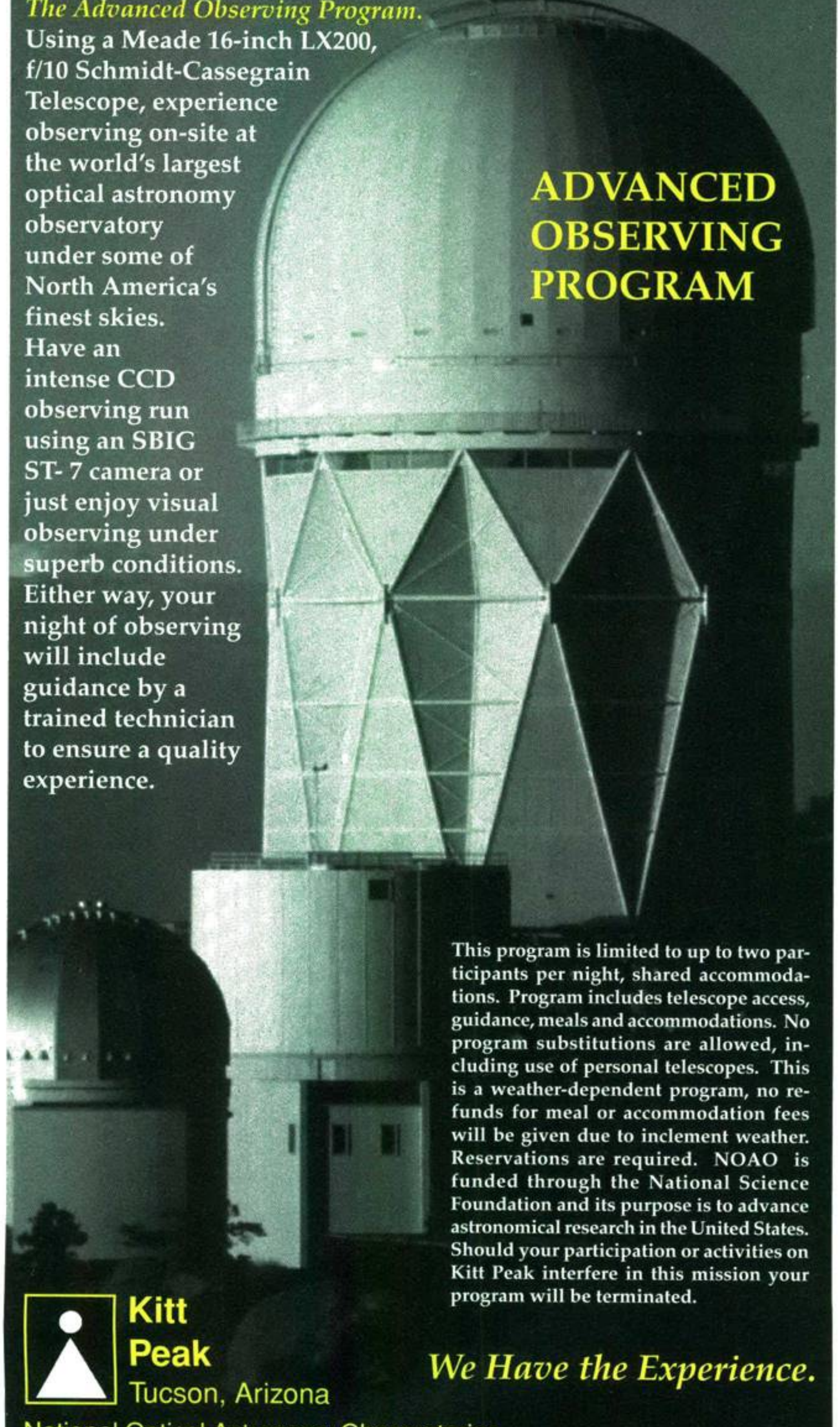

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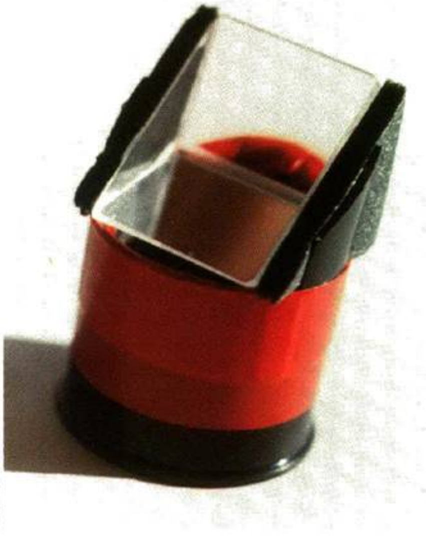

Frank L. Tabrah

Cut the film canister as illustrated in the photo (above) to hold the prism and serve as a slip-on tube. Mount the prism in the cut end of the film box with the rubber and glue. Shim the inside of the film canister with thin rubber sheeting so that it fits nicely (but still slides) on the outside of your finder tube. This allows you to attach or remove the prism assembly as needed. Wrapping the unit with tape will improve both its appearance and strength. — *Frank L. Tabrah, Honolulu, Hawaii* **A**

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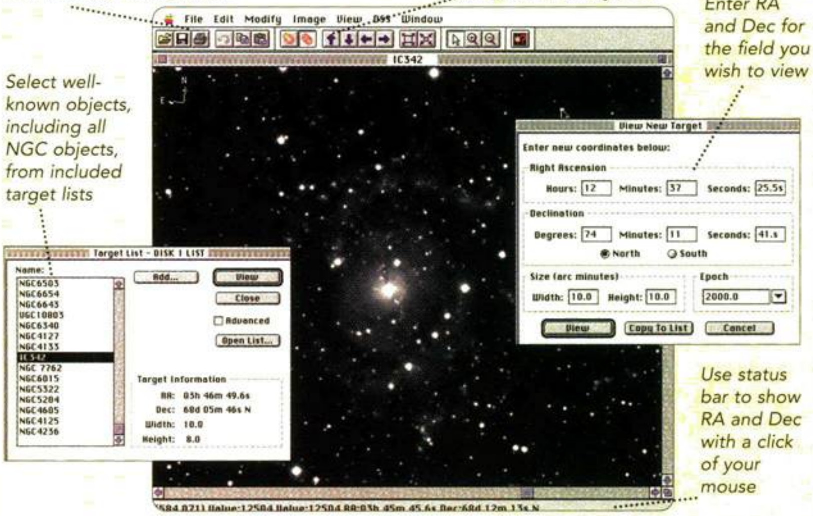

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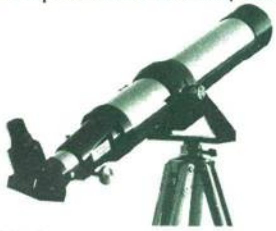

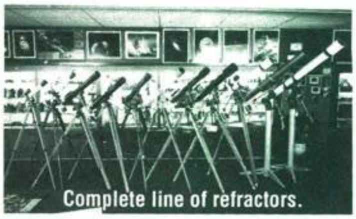
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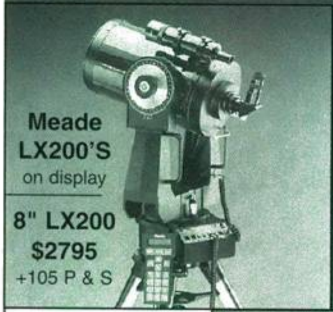
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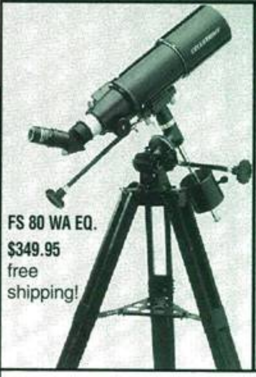
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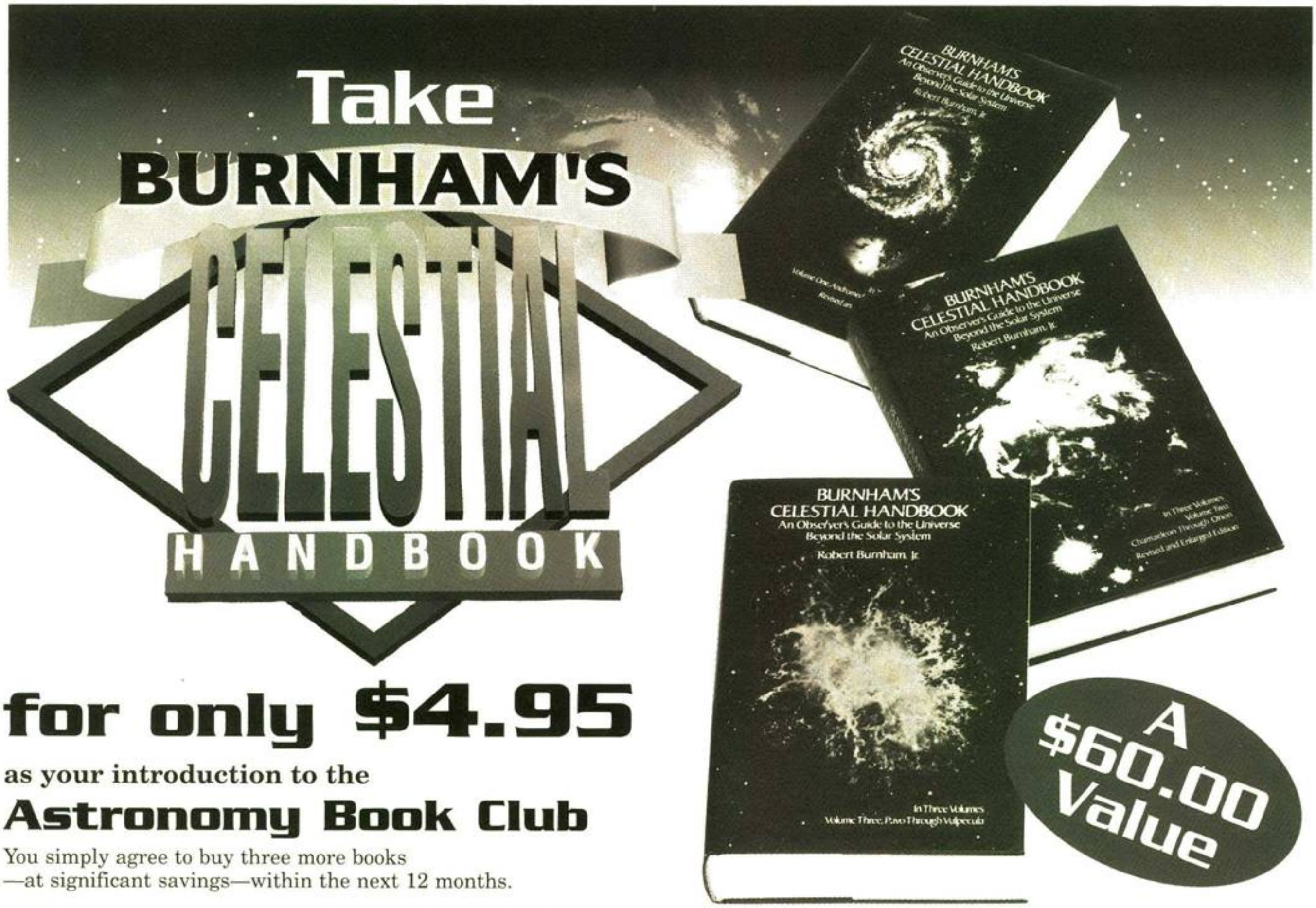
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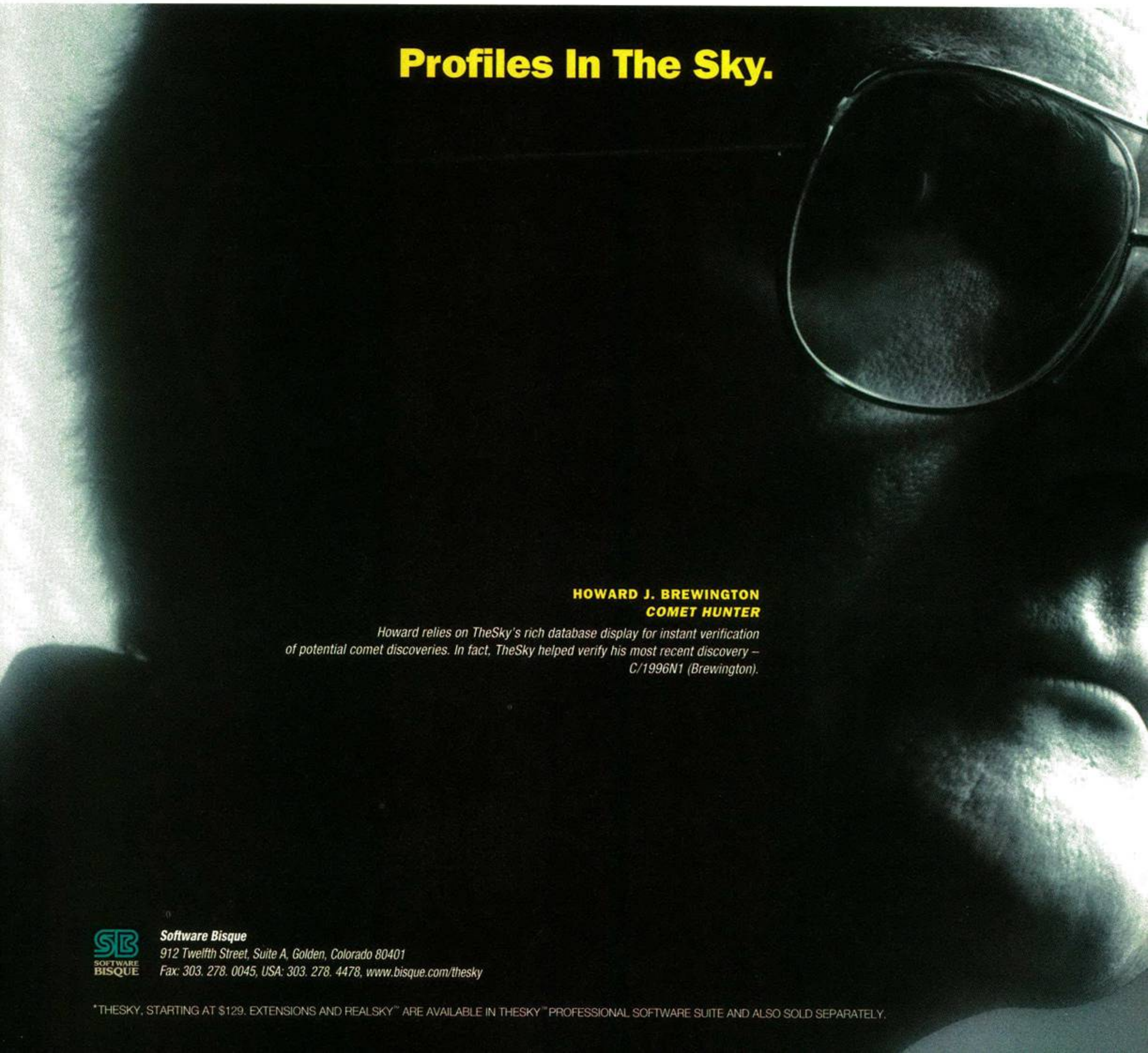
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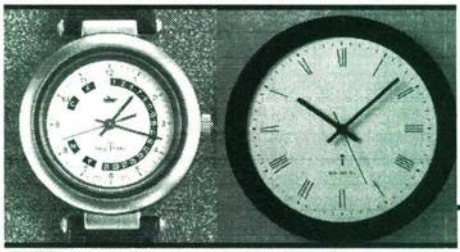

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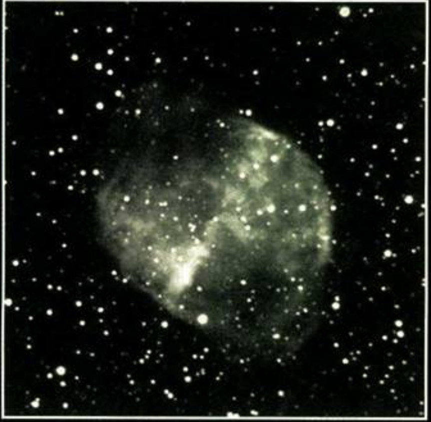
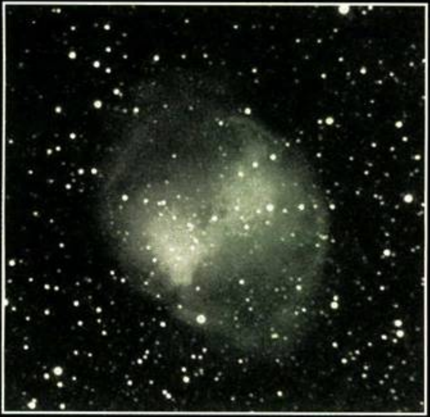
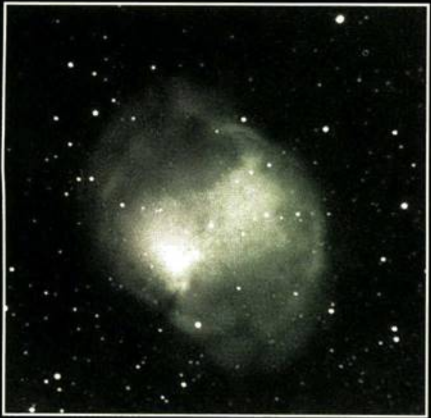


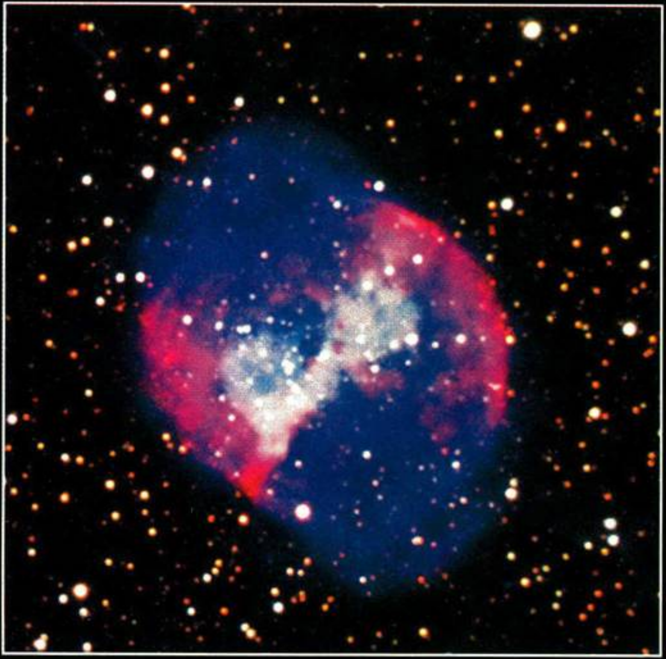
M27 Planetary Nebula. *1800 second exposure taken through a Red filter with the Model ST-7 CCD Imaging Camera and the CFW-8 Color Filter Wheel.*



M27 Planetary Nebula. *1800 second exposure taken through a Green filter with the Model ST-7 CCD Imaging Camera and the CFW-8 Color Filter Wheel*



M27 Planetary Nebula. *1800 second exposure taken through a Blue filter with the Model ST-7 CCD Imaging Camera and the CFW-8 Color Filter Wheel.*



M27 Planetary Nebula. As in all the planetary nebulae, the faint central star is an abnormally hot bluish dwarf with a spectrum resembling that of an ancient nova and a calculated surface temperature of about 85,000 degrees K., one of the hottest stars known. It is assumed that planetaries are formed by ejection of material from the hot central star, but the exact details of the process are unknown. Red, Green, and Blue Model ST-7 images were summed together and color balanced to create a true color image. *Courtesy of Benoit Schillings.*

Note: All images were processed from a computer disk to a standard photographic film using a Film Recorder. Courtesy of AstroPhoto, Oakview, California.

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GALACTIC EVOLUTION

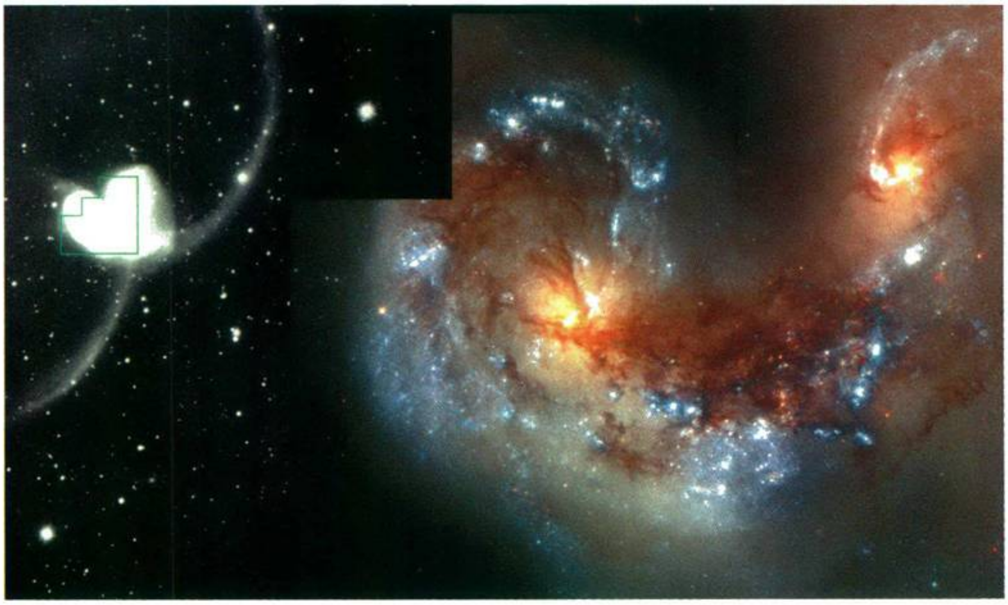
Fireworks in the Antennae

Galactic collision sparks starbirth

▶ When two galaxies collide, their individual stars are so small and spread so far apart that it's unlikely any of them would ever bump into one another. But if you suspect that galaxies can't survive such an extraordinary event completely unscathed, you are indeed correct. Galactic collisions produce spectacular celestial fireworks displays. The galaxies' gas clouds — which measure tens or hundreds of light-years across — smash into one another, collapse, and form millions of new stars in an intense burst of star formation.

A new Hubble Space Telescope image shows the aftermath of such a catastrophe: more than 1,000 exceptionally bright star clusters in the Antennae (NGC 4038 and NGC 4039), a pair of colliding spiral galaxies 63 million light-years away in the southern constellation Corvus. The clusters' blue colors indicate young, massive stars, many of which are only a few million years old. By dating the clusters, astronomers will be able to retrace the collision step-by-step.

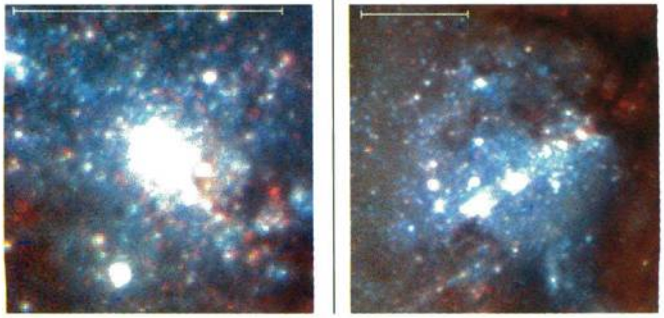
The Hubble image also shows that the Antennae's brightest clusters contain one million stars and are extremely compact, the size and shape of the Milky Way's largest globular clusters. This may be more than mere coincidence. Because the Milky Way's globular clusters contain old stars, astronomers have long thought that they formed early in the galaxy's history. But the images of the Antennae star clusters hint that some globular clusters in other galaxies have formed more recently in galactic collisions.


Brad Whitmore (STScI), et al., and NASA

A ground-based image (left) and a Hubble Space Telescope image (right) catch two spiral galaxies in the process of merging. The system is known as the Antennae, because the long tails resulting from tidal interactions bear a superficial resemblance to insect antennae. The orange blobs in the color image are the cores of the two galaxies.

The deeper astronomers look into space, the more such galactic mergers they see. But never before have they seen a collision in such magnificent detail. "The discovery will help us put together a chronological sequence of how colliding galaxies evolve. This will help us address one of the fundamental questions in astronomy: Why some galaxies are spirals while others are elliptical in shape," says Brad Whitmore of the Space Telescope Science Institute.

Because the Milky Way Galaxy and the Andromeda Galaxy (M31) may collide some five billion years hence, the Antennae gives us a possible sneak preview of our own galaxy's future.



The Antennae galactic collision triggered intense star birth, resulting in brilliant blue star clusters containing up to one million stars. The scale bars represent 1,500 light-years.

Brad Whitmore (STScI), et al., and NASA

MARS GLOBAL SURVEYOR

Mixed News from Mars

▶ The news from Mars Global Surveyor is mixed. On the up side, the spacecraft has revealed that Mars's weak magnetic field has a patchy structure. The field is 1/800 the strength of Earth's

(see "Mars" on page 26)

BREAK THROUGH FOCUSER DESIGN FROM JMI

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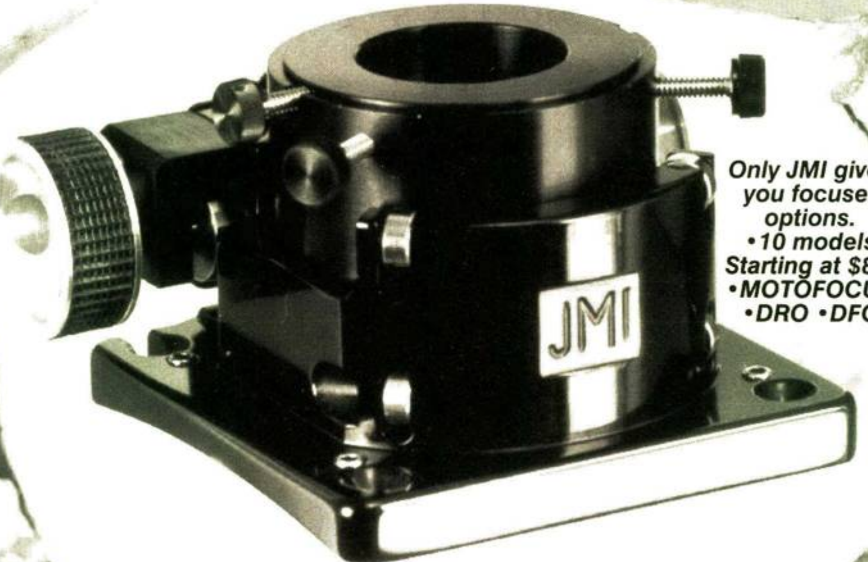

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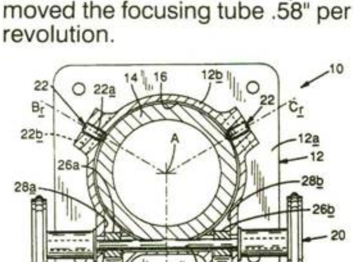

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JMI's motto: Strive constantly to surpass yourself not the competition.

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- Summer 1992, JMI develops the first NGF-S (for SCTs)
- October 1992, JMI patents first one-piece Crayford focuser.
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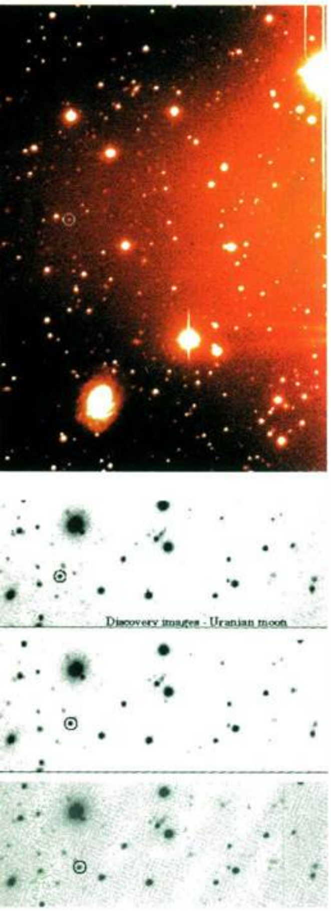


Two new moons of Uranus were recently discovered with the 200-inch Hale Telescope on Palomar Mountain. The fainter satellite (circled in top image) appears at 22nd magnitude; the glow from Uranus itself can be seen off the right edge of this image. The brighter satellite (bottom three images) glows at 21st magnitude and can be seen moving against the background stars in this sequence.

Brett Gladman (University of Toronto), et al.

SOLAR SYSTEM

Two More Moons for Uranus

▶ Astronomers using the 200-inch Hale Telescope on Southern California's Palomar Mountain have discovered two new satellites orbiting Uranus. The moons — the faintest ever detected with a ground-based telescope — are estimated to be only 50 and 100 miles (80 and 160 km) in diameter.

Brett Gladman of the University of Toronto, Philip Nicholson and Joseph Burns of Cornell University, and J. J. Kavelaars of McMaster University first observed the objects on September 6 and 7, 1997. The team found the objects — preliminarily designated S/1997 U1 and S/1997 U2 — by comparing photographs taken one hour apart and looking for objects that had moved against the background of fixed stars.

The two new moons are the first "irregular" satellites seen orbiting Uranus. With this discovery, Uranus finally joins the rest of the gas-giant planets, which all have satellites that follow eccentric and inclined orbits far from their planets. Uranus's previously known 15 moons follow more typical orbits — nearly circular and in the plane of the planet's equator — between 30,000 miles and 362,000 miles (50,000 km and 584,000 km) from Uranus. The orbits of the new moons are inclined to the equatorial plane and take their satellites on eccentric paths that, in the case of S/1997 U2, range from two million to 5.5 million miles (three million to nine million km) from Uranus.

The astronomers speculate that the moons once orbited the sun until they were captured by Uranus's gravity. "The larger of the two satellites appears quite red, which may indicate a hydrocarbon surface that was bombarded by energetic particles from space," says Burns.

"We'll get a rough idea of their shape by watching the objects as they rotate," says Nicholson, "but they really need to be visited by spacecraft to get fine details." The only time a spacecraft visited Uranus was in 1986 when Voyager 2 flew by. During its pass, Voyager identified 10 new moons orbiting Uranus, adding to the five that had been spotted previously by Earth-based telescopes. — ALLEN ZEYHER

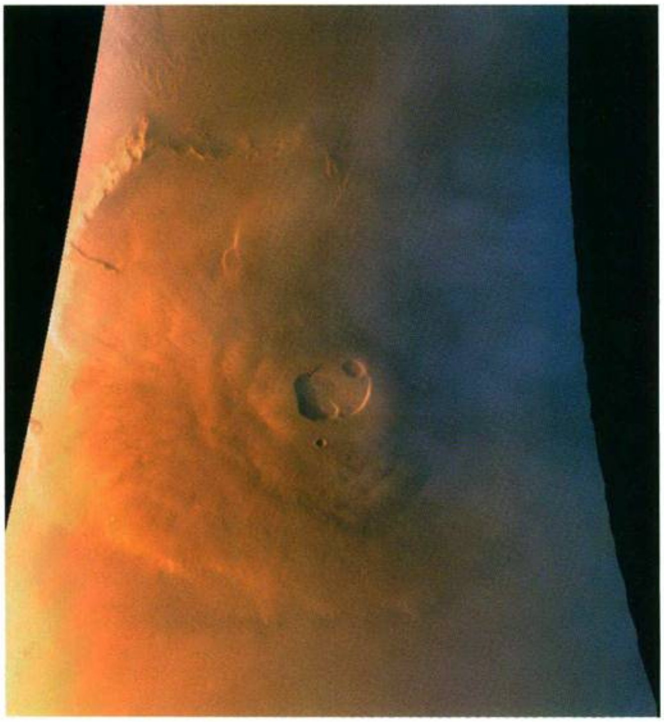
(Mars)

field in many regions, but stronger in others.

Mars's patchy field is probably a fossil field, frozen into lava rocks. When lava cools, the rocks solidify and drop below their so-called Curie temperature. At that point, the magnetic domains inside the iron-bearing minerals freeze into a position aligned with whatever magnetic field exists around them at that time. If ancient Mars had a magnetic field, lava flows in different regions of Mars may have "fossilized" that field. Measuring the fossil field associated with different flows could tell us a lot about Mars's history, including the history of the planet's iron core activity.

On the down side, on October 12, 1997, ground controllers were forced to temporarily suspend the atmospheric aerobraking maneuver that would circularize the spacecraft's orbit into a low-altitude mapping orbit. One of the two 11-foot-long solar panels failed to lock into position, so controllers were concerned that additional aerobraking would put undue stress on that panel.

After controllers analyzed the problem, they were able to resume aerobraking in early November — but at a more gradual pace. Instead of attaining its 248-mile-high circular mapping orbit in March 1998, the spacecraft won't begin its final mapping orbit until January 1999. The new mapping orbit will be a mirror image of the originally planned orbit and will preserve all of the mission's scientific objectives. "Instead of taking data from north to south on the sunny side of Mars, Global Surveyor will be


NASA/JPL/Malin Space Science Systems

Olympus Mons, seen in this new Mars Global Surveyor image, towers 15 miles (23 km) above the martian plains. With a base that covers hundreds of miles, it ranks as the largest volcano in the solar system.

LARGE APERTURE

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Celestron International • 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835 making its observations in a south to north direction also in the sunlight," said project manager Glenn Cunningham of NASA's Jet Propulsion Laboratory.

Despite the problems with aerobraking, the scientific instruments continue to perform flawlessly. The spacecraft's current elliptical orbit brings it as low as 77 miles above Mars, where it has returned exceptionally high resolution images of the dust-strewn surface.

— WILLIAM K. HARTMANN,
PLANETARY SCIENCE INSTITUTE

EXTRASOLAR PLANETS

Proxima Planet?

Sun's nearest stellar neighbor may have a planet

▶ Proxima Centauri, the closest star to the sun, might be orbited by a giant planet or a brown dwarf according to a paper in the January 1998 *Astronomical Journal*. Images taken on July 1, 1997, and October 13, 1997, by the Hubble Space Telescope's Faint Object Spectrograph show a faint light source within 0.5 arcsecond of Proxima. This light source moved during the 103-day interval, as one would expect for an orbiting companion.

"We did see something, we don't know what it is. We tried to explain it away as an instrumental effect but couldn't," says Al Schultz of Computer Sciences Corporation, leader of the 13-member team that observed Proxima. Based on the brightness of the mysterious point of light, Schultz thinks it is probably a brown dwarf, although it could also be a giant planet. With a separation of less than 0.5 arcsecond, the companion, if it exists, could be about two-thirds of the Earth-sun distance from Proxima.

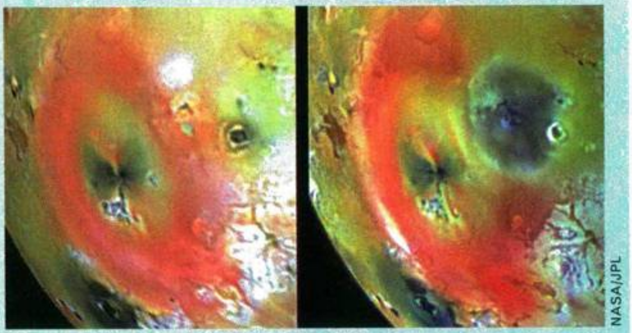
Fritz Benedict of the University of Texas at Austin, a member of Schultz's team, expresses caution. For the past four years he has been tracking Proxima Centauri's motion across the sky with the Hubble Space Telescope's Fine Guidance Sensors. He's been looking for perturbations induced by a massive orbiting companion. "I'm puzzled by the Hubble images because I don't see any wobbles," says Benedict. "This new result is very interesting and requires an explanation. But it's very difficult to come up with a scenario that agrees with both types of observations. But if there is an object there, it's a spectacular discovery."

Planet hunter Geoff Marcy of San Francisco State University adds, "Fritz's work is extraordinarily strong. There are two pieces of information here and they don't fit, and remember that non-detections have more credibility than detections."

Schultz's team plans to image Proxima with Hubble's NICMOS infrared camera in early 1998. Because a planet or brown dwarf will appear brighter in infrared light than visible light, the NICMOS images will tell the tale.

Proxima Centauri is a small, cool star only 4.2 light-years from Earth. It belongs to a triple star system, of which the other two members, Alpha Centauri A and B, are similar to the sun in size, temperature, and luminosity. Proxima orbits Alpha Centauri A and B at a distance of about 13,000 times the Earth-sun distance (330 times the average Pluto-sun distance).

GALILEO



NASA/JPL

A MASSIVE ERUPTION the size of the state of Arizona wracked the surface of Jupiter's volcanically active moon Io during mid-1997. The dramatic changes caused by the eruption show up in two images from the Galileo spacecraft, one taken during the spacecraft's seventh orbit on April 4 (left), the other during the tenth orbit on September 19 (right). The huge eruption appears as a dark spot 250 miles (400 kilometers) in diameter at the upper right of the second image.

The dark spot surrounds a volcano named Pillan Patera. During its ninth orbit, Galileo imaged a volcanic plume rising 75 miles (120 km) above the surface at this location. The even larger, reddish deposit to the left of Pillan belongs to the active volcano Pele. It also shows marked changes between the two images, perhaps caused by the interaction of the two large plumes.

MARS EXPLORATION

Farewell to Mars Pathfinder

Depleted battery and cold temperatures fell lander

▶ Scientists and engineers knew that Mars Pathfinder's days were numbered. Still, they are disappointed that the mission has probably come to an end. They have received no images or data from the lander since September 27, 1997, and the last "beep" was heard on October 7. "We concede that the likelihood of hearing from the spacecraft diminishes with each day," says project manager Brian Muirhead of the Jet Propulsion Laboratory. "We will scale back our efforts to reestablish contact but not give up entirely."

While NASA engineers aren't sure why Pathfinder has fallen silent, they think it's probably due to the depletion of the lander's battery power combined with falling temperatures at the landing site.

Nevertheless, the mission has been a resounding success. The lander and rover were designed for minimum lifetimes of 30 days and seven days respectively, yet they returned images and data for 84 days. The lander returned more than 16,000 images along with a wealth of data about the martian atmosphere. The rover returned 550 images and conducted 20 chemical analyses on martian rocks and soils. This information will occupy scientists for many years.

The mission also demonstrated a low-cost means of landing on Mars using cushioning airbags and that

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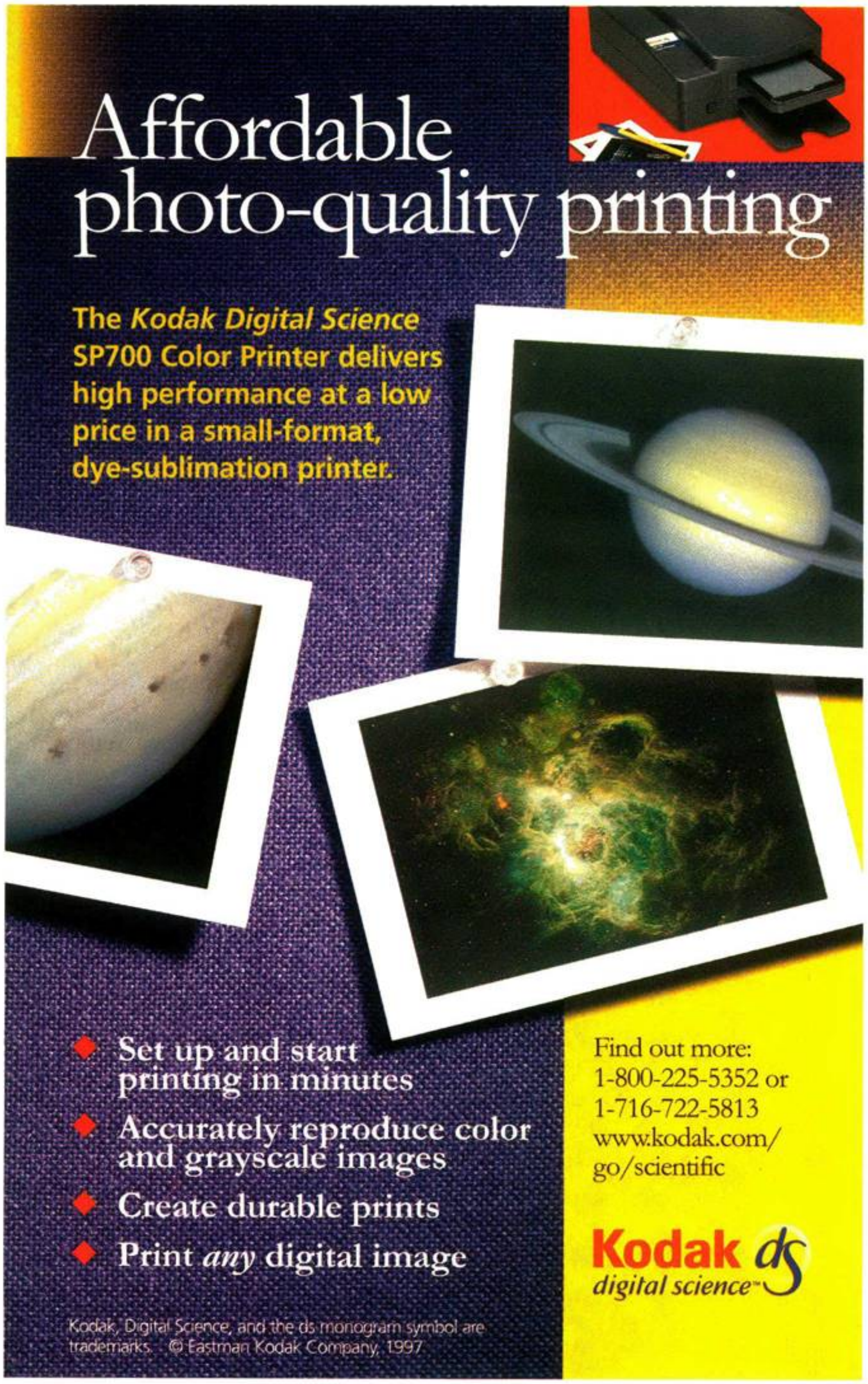

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semi-autonomous rovers can be successfully operated on another planet. "In every respect, Pathfinder exceeded expectations," said Muirhead, who added, "It has set the tone for the future of space exploration. New missions are being done in the Pathfinder mode. The American people will get a lot more bang for their buck doing missions this way than they have in the past."

More details of the mission's primary science results, including a 3D 360° panorama of the martian surface, will appear in next month's issue.

STELLAR ASTROPHYSICS

Are All Stellar Black Holes the Same Size?

Six of seven black holes have virtually same mass

▶ Stars come in all masses, from pip-squeaks only a tenth the mass of the sun to behemoths containing 100 solar masses. Most astronomers thought that the black holes created when the more massive stars died would likewise exhibit a broad range of masses — starting at about three times the mass of the sun and going up to dozens of solar masses.

Now, Yale University astronomer Charles Bailyn and his colleagues have studied seven black holes in binary systems in our galaxy and found that six of them come in with nearly equal masses: about seven times the sun's mass. This surprising result, which no one has yet been able to explain, eventually could help astronomers better understand how black holes form.

When a star containing much more mass than the sun runs out of nuclear fuel, it is doomed to a quick death. A core of iron builds up inside the star but, because iron fusion can't produce energy, the weight of the overlying layers crushes the core, causing it to collapse. A shock wave forms, blasting the outer layers of the star into space in a spectacular explosion called a supernova.

But what of the iron core left behind? If the core has less than about three solar masses, it should collapse into a neutron star. A neutron star's internal pressure can't support anything heavier than that, however, so more massive objects must collapse all the way to a black hole, an object so dense that its gravity won't allow even light to escape.

Nothing in this scenario hints at a reason why black holes should come in cookie-cutter sizes. "Something about the collapse of a star in a supernova explosion — or perhaps in the evolution of the binary system that creates it — seems to favor retaining about seven solar masses in the black hole and blowing the rest of the star back into space," says Bailyn. (The seventh black hole contains 10 to 14 times the mass of the sun and suggests there may be a second subgroup.) "This new finding will send astrophysicists back to their supernova computer models to try to figure out why."

WEBSITE

Check *Astronomy*'s website for news as it happens — http://www.astronomy.com

X-33 Given the Go-Ahead

A design review panel of NASA, U.S. Air Force, and industry representatives has given the thumbs up to NASA's X-33, a billion-dollar prototype for a single-stage-to-orbit reusable launch vehicle (a "space plane"). The X-33 will fly 15 times the speed of sound at altitudes approaching 60 miles. The approval means that the major contractor, Lockheed Martin, can proceed with construction of the remaining components. If all goes according to plan, the X-33's first test flight will take place in July 1999.

Are Tilted Planets Habitable?

In 1993, French astronomer Jacques Laskar pointed out that without the moon, Earth's spin axis would vary chaotically between tilts of 0° and 85°, exposing both hemispheres to extreme climate conditions and making conditions hostile for life. But in a paper in the September 1997 *Icarus*, Darren Williams and James Kasting of Penn State University argue that many such planets could harbor life. Their simulations of Earth-like planets with tilts up to 90° show that those with large continents, or those near the far end of their star's habitable zone, would still have temperate, life-supporting climates.

Cassini off to Saturn

The Cassini spacecraft roared off its launch pad on a Titan IV/B Centaur rocket at 4:43 a.m. EDT on October 15, 1997. The picture-perfect launch from Cape Canaveral marked the start of a long journey to Saturn that includes two flybys of Venus, one of Earth, and one of Jupiter to give Cassini enough speed to reach the Ringed Planet. So far the spacecraft has performed flawlessly, including a 35-second burn of the main engine on November 9 to tweak its trajectory. Cassini will reach Saturn on July 1, 2004.

NASA

Cassini begins its ambitious mission to the Ringed Planet.

A Nearby Luminous Quasar

A team of Brazilian astronomers led by Carlos Torres of the Laboratorio Nacional de Astrofisica has discovered a luminous quasar, PDS 456, only 2.5 billion light-years away (which is much closer than most quasars). PDS 456's quasar was difficult to discern because it lies hidden behind the Milky Way's dust. Once Torres's team calculated the dimming due to dust, they determined that PDS 456 is 1.3 times more luminous than the nearest known quasar, 3C 273, making it the most luminous quasar within four billion light-years.

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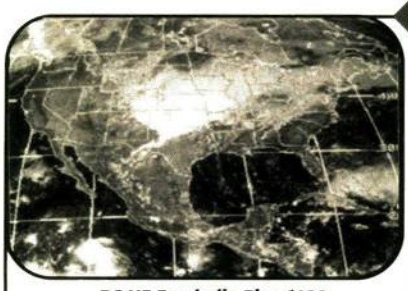

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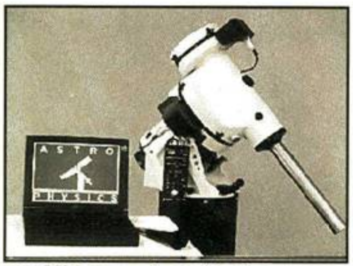

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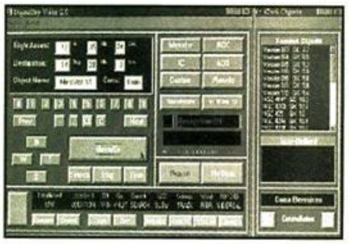

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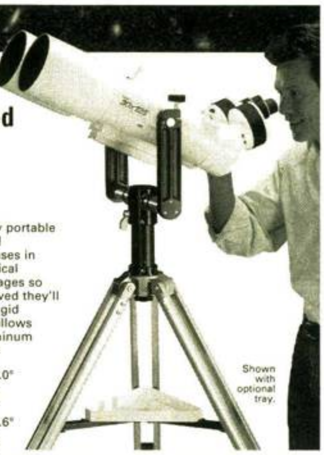

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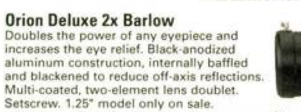

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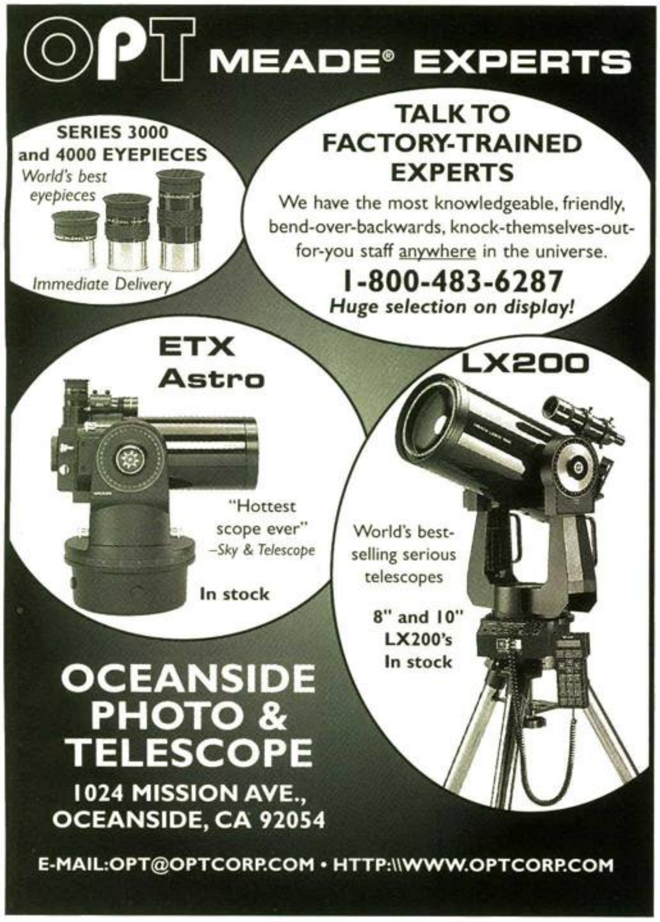
ASTRONOMERS

LOOK BACK

THE A LIST:

Although they didn't make their living at astronomy, these 25 luminaries left their mark.

- *American photographer Edward Emerson Barnard discovered nine comets by 1887, when he was hired to work at Lick Observatory.*
- *American watchmaker William Bond discovered Saturn's moon Hyperion in 1848 and Saturn's faint Crepe Ring in 1850.*
- *Sherburne Burnham, an American court stenographer (and later clerk of the U.S. District and Circuit Court of Chicago), discovered more than 1,300 visual double stars between 1870 and 1913.*
- *English brewer Richard Carrington found that the sun does not rotate as a solid body and recorded the first solar flare.*
- *William Dawes, an English clergyman, discovered and observed thousands of double stars between 1826 and 1868. He also independently discovered Saturn's Crepe Ring.*
- *English printer Warren de la Rue was a pioneer astrophotographer whose photographs of an 1860 total solar eclipse helped prove that prominences were phenomena of the sun and not the moon.*
- *American physician Henry Draper helped bring spectroscopy into astronomy, taking the first spectrum of a star (Vega) in 1872 and spectra of the sun, planets, other stars, and the Orion Nebula.*
- *Since 1981, Reverend Robert Evans of Australia has discovered 36 supernovae — more than any other visual observer in history.*
- *Englishman John Goodricke discovered periodic brightness changes in the star Algol and suggested they might be caused by an unseen orbiting companion.*
- *German-English musician William Herschel discovered the planet Uranus in 1781, its moons Titania and Oberon six years later, and Saturn's moons Mimas and Enceladus two years after that. His discovery and observations of more than 800 double stars showed that many were gravitationally bound, the first evidence that Newton's laws held outside the solar system.*
- *Between 1834 and 1838, John Herschel, the wealthy son of William, discovered well over 1,000 nebulae and a similar number of double stars, extending his and his father's work to the Southern Hemisphere.*
- *Caroline Herschel, the sister of William, discovered eight comets and admirably assisted her brother, becoming the first accomplished woman astronomer.*
- *In 1864, English silk merchant William Huggins showed that stars were made of the same elements that exist on Earth and discovered that some nebulae were gaseous while others (now known as galaxies) consisted of stars.*
- *Wealthy Dutchman Christiaan Huygens discovered Saturn's moon Titan in 1655 and deduced that the rings were thin and nowhere touched the planet.*
- *English brewer William Lassell discovered Neptune's large moon Triton in 1846, codiscovered Saturn's moon Hyperion in 1848, and discovered Uranus's moons Ariel and Umbriel in 1851.*
- *Percival Lowell, a wealthy American, predicted the existence of a planet beyond Neptune, which was discovered at Lowell Observatory in 1930, 14 years after his death.*
- *An American Unitarian minister, American Joel Metcalf discovered six comets, 41 asteroids, and many variable stars. At his death in 1925, he was working on the 13-inch lens with which Pluto would be discovered.*
- *German physician Heinrich Olbers discovered the asteroids Pallas and Vesta in the 1800s as well as five comets and devised a simplified way to calculate a comet's orbit.*
- *William Olcott, an American lawyer, helped found the American Association of Variable Star Observers in 1911 and wrote Field Guide to the Stars, a classic, popular book on astronomy.*
- *In the 1840s, Irish landowner William Parsons, the third earl of Rosse, built a 72-inch telescope (the largest of its time) and with it discovered spiral structure in many nebulae.*
- *Leslie Peltier, an American draftsman and toy designer, discovered 12 comets and several novae while making more than 130,000 measurements of variable stars from the 1910s to 1980.*
- *Between 1801 and 1827, Frenchman Jean-Louis Pons discovered or codiscovered a record 37 comets, three-fourths of all comets found in that period.*
- *American architect, arctic explorer, and amateur telescope maker Russell Porter inspired thousands to build their own telescopes through a series of articles in Scientific American during the 1920s. He also contributed to the 200-inch Hale Telescope project.*
- *American electronics engineer and radio ham Grote Reber built the first radio telescope in 1937 and used it to discover the brightest radio sources in the sky. For a decade, he was the world's only radio astronomer.*
- *German pharmacist Samuel Schwabe discovered that the number of sunspots varies with an 11-year period.*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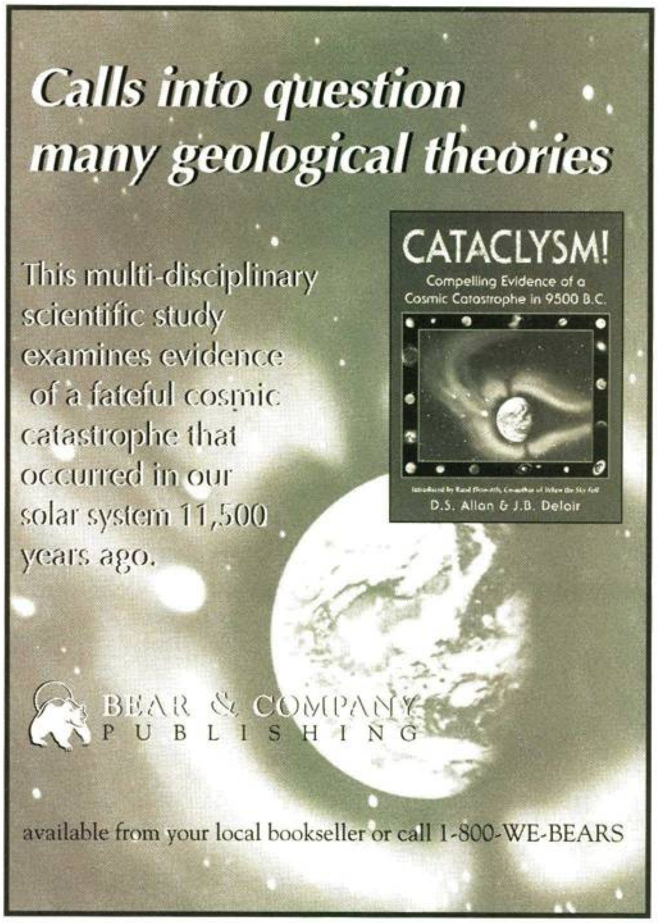
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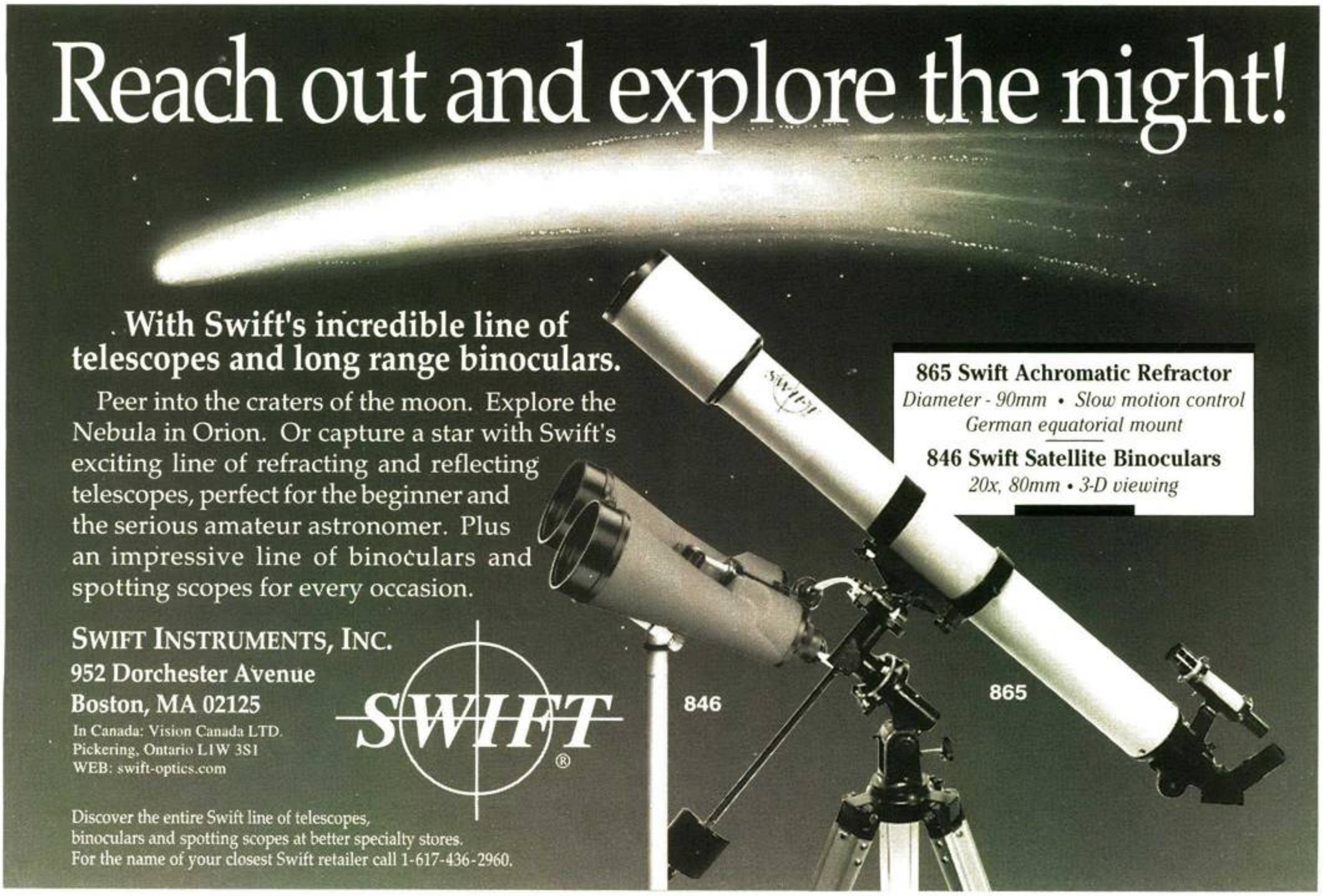
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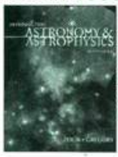

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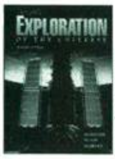

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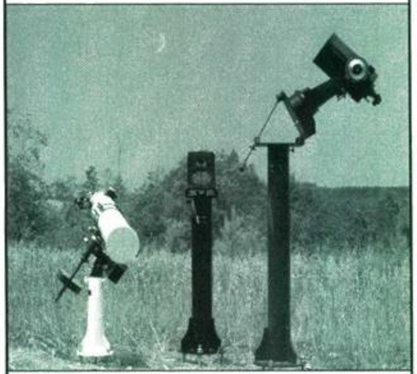

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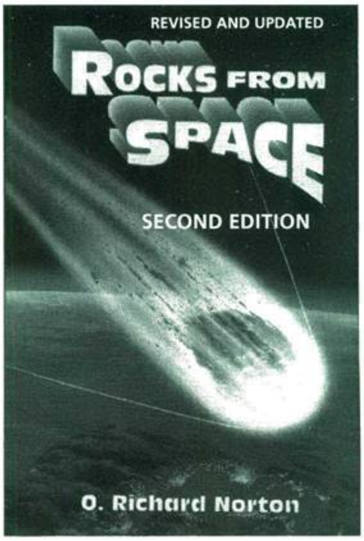

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Origins of Everything

From a white-hot Big Bang to planets and people is a long and extraordinary journey. — Stephen Hawking

Where did we come from? How did we get here? Until the 20th century, these were questions generally left for philosophers and theologians: The knowledge required to answer these questions simply did not exist. Modern science has proven to be the powerful tool needed to pry open the vault containing nature's best kept secrets. As we prepare to enter a new millennium, humanity has a basic, though incomplete, understanding of where we came from and how we got here.

In this special issue, *Astronomy* traces the critical steps leading from the Big Bang to the formation of planets — the prerequisites for life. To a hypothetical, supernatural observer who came into existence at the moment of the universe's creation some 12 billion years ago, it probably would have seemed inconceivable that intelligent beings would ever emerge out of the blinding chaos. The Big Bang spewed matter helter-skelter, creating a featureless primordial soup of energy and subatomic particles. As the matter spread outward during cosmic expansion, most of the universe was destined to thin out into an immense void of virtual nothingness, with only an occasional atom sprinkled across the vast and frigid depths of space.

The story of our origins is largely a tale of matter clumping together. From the vast smoothness resulting from the Big Bang, the forces of nature somehow concentrated enough matter together in a few places to fashion the structure that would eventually make life possible. Galaxies, stars, planets, and people — these are places of greatly enhanced density, the odd spots of the universe where matter has gathered together to form complex structures. Follow along as our four-part series on Origins takes you on a cosmic journey from the Big Bang to planets:

COSMIC STRUCTURE From the smoothness created by the Big Bang, the energy of empty space may have planted the seeds from which galaxies and large-scale structures could grow.

ELEMENTS Within the primordial soup of subatomic particles and inside the nuclear furnaces of stars, elements — the building blocks of all complex objects — form.

STARS Out of the frigid and nearly empty expanses of space, gravity brings gas and dust together to create stars.

PLANETS Inside whirling disks left over from star formation, gas and dust clump together to build planets.

Astronomy's sister publication *Earth* picks up the story from here this month in its own special issue devoted to Origins. The first two articles discuss the origin of Earth's nickel-iron core and silica-rich crust. The third article ponders the origin of life and wonders if life on Earth got its start near deep sea vents. The final article probes the origin of the modern oceans and speculates about whether the rising of the Isthmus of Panama three million years ago indirectly led to the origin of *Homo sapiens* half a world away.

We don't know if similar processes led to others out there like us — intelligent, conscious beings who have developed the abilities to ask questions about their own origins. But we do know that at least on one small planet, orbiting an ordinary star in the outskirts of a normal spiral galaxy, intelligent beings emerged who could ask such questions. In perhaps nature's most miraculous transformation, the universe evolved the capacity to ponder and understand itself.

Planting Pri

Everything we see around us may have started out as tiny fluctuations in the primordial soup of the early universe.

by Rocky Kolb

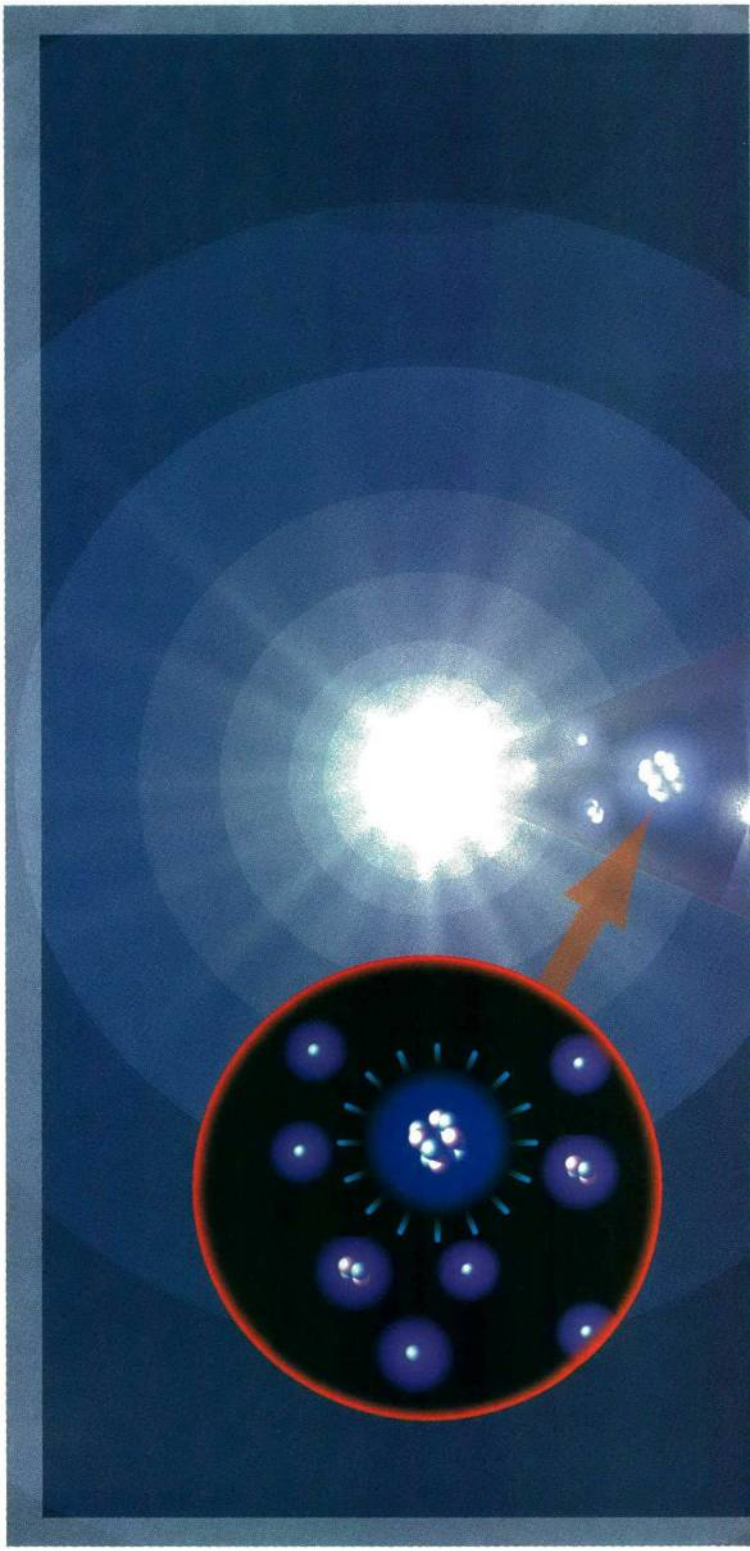
HE SPOKE SOFTLY WITH A PIPE CLENCHED IN his teeth. He mumbled a lot, and English wasn't his native language. His closest colleagues had trouble understanding him speaking any language, even his native Danish. It was hard to believe that anyone would bother attending his series of public lectures. But his poor communication skills didn't cool the feverish excitement in the crowded lecture hall on the campus of the University of California at Berkeley. For in the audience that day were young graduate students burning with the inner fire of committed revolutionaries, and they were there to listen to a decorated hero of the revolution.

In the tumultuous year of 1937, in the midst of a worldwide economic depression, with a civil war raging in Spain, fascists in control of Germany and Italy, and Japan and China about to go to war in Asia, the world seemed to be coming apart. Talks about revolutions were common on college campuses.

But the speaker that day was an uncommon revolutionary. He was not concerned with the Russian Revolution that had occurred 20 years earlier, or any other political or social revolution. He spoke of a much more profound and far reaching revolution. He spoke of a revolution that inevitably would shape society in ways a mere political revolution could not.

Niels Bohr was one of the great heroes of 20th century physics, decorated with the 1922 Nobel Prize for the "Study of Structure and Radiations of Atoms." He was at the forefront of the struggle to develop the laws of quantum mechanics, the bizarre and counterintuitive set of rules that governs the behavior of matter on submicroscopic scales. Bohr was the father of the revolution that overthrew our understanding of the laws of the natural world that had ruled physics since the time of Newton and replaced them with a new order that included radical concepts such as the uncertainty principle, quantum levels, and quantum fluctuations.

When Bohr spoke in Berkeley that day in 1937, the revolution of quantum mechanics had not caused much of a



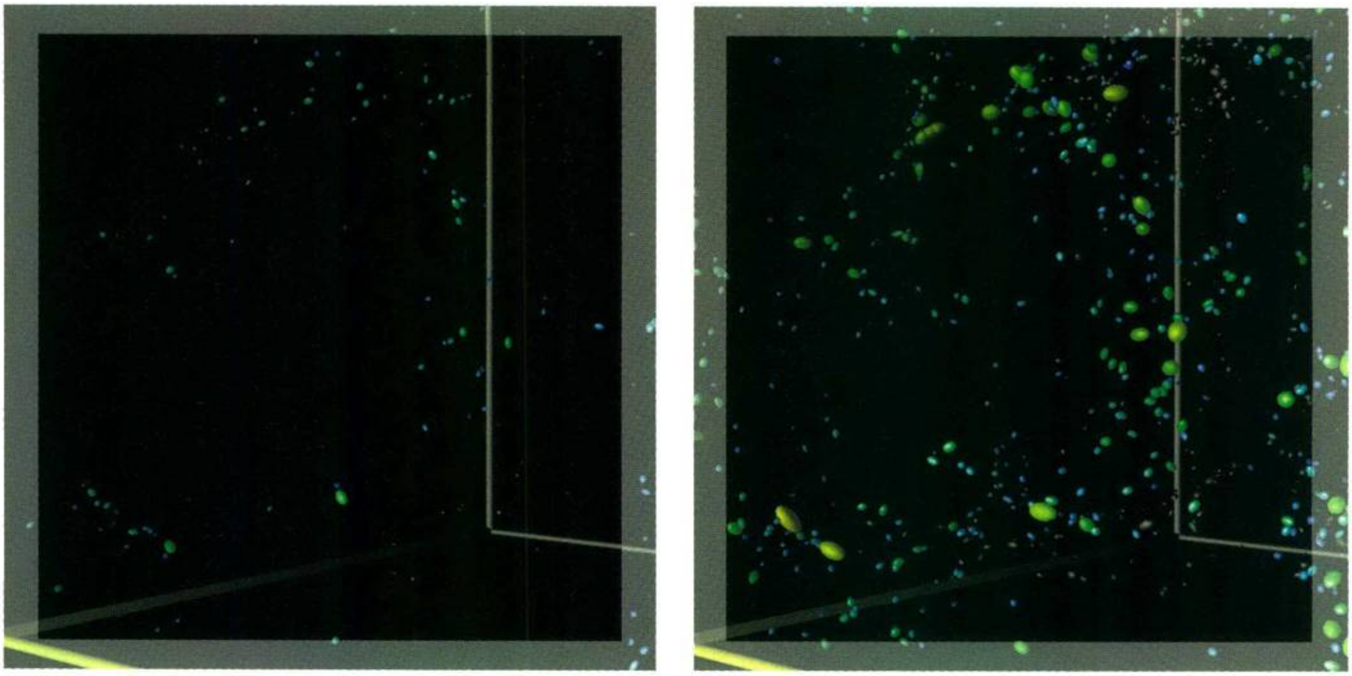
Quantum fluctuations moments after the Big Bang concentrated matter into primordial seeds, enabling gravity to form the galaxies, stars, planets, and people we see in the modern-day universe.

mordial Seeds

George Krauter

ripple beyond a small community of physicists in the cloistered halls of universities and research labs. It would be decades before knowledge of the quantum world would change the everyday world by paving the way for the development of transistors, lasers, magnetic resonance imaging, digital computers, and all the products of our electronic society (and yes, nuclear weapons). Those of us over 40 years of age can recall what life was like before the quantum revolution spilled out of physics laboratories into electronics stores, but children living in the industrialized world cannot imagine what life would be like had the quantum world never been discovered.

Somewhere in the crowded auditorium that day was a young physics graduate student named Philip Morrison. Now Institute Professor Emeritus at MIT, distinguished astrophysicist, and well known science writer, he was then just another young face in the audience in awe of the great Bohr. The experience must have left quite an impression, because even 60 years after the event, Morrison vividly recalls Bohr's lecture, as well as one particular question asked of Bohr after the lecture.



All photos these pages: Patrik Jonsson, Michael Gross, and Joel Primack (University of California at Santa Cruz)

Supercomputers model the evolution of large-scale structure over billions of years of cosmic history. The colored balls indicate concentrations of matter, i.e. galaxies.

In the post-lecture question period someone asked Bohr what he thought of recent advances in cosmology, the branch of extragalactic astronomy concerned with the origin and arrangement of the universe. After all, the 1920s and 1930s were just as revolutionary for extragalactic astronomy as they were for physics. In 1924 Edwin Hubble extended the size of the known universe when he proved that "spiral nebulae" were distant galaxies like our own Milky Way. In 1929 Hubble's observations led to another fundamental discovery when he showed that distant galaxies are rushing away from us in an explosion of space we now call the Big Bang. By 1937 Hubble was charting the universe with the 100-inch Mt. Wilson Hooker Telescope and studying how galaxies are spread throughout space.

Lots of theoretical work in cosmology occurred in the 1920s and 1930s. By 1937 Aleksandr Friedmann in Russia and Georges Lemaître in Belgium had proposed the big-bang theory for the origin of the universe. Even Einstein, who had originally dismissed the possibility of an expanding universe, by then had accepted the idea of a Big Bang. It must have been puzzling that Bohr didn't mention cosmology in his lectures about the frontiers of physics.

Bohr's reply might have been even more surprising than his omission of the subject. He answered that although the astronomical observations and cosmological theories were important, a true understanding of the origin and structure of the universe was impossible without first understanding how the laws of quantum mechanics operate on the fundamental particles, and in 1937 physicists were a long way from that goal. He said that until cosmology and particle physics could be brought together in the same context, he did not have much hope for real progress in cosmology.

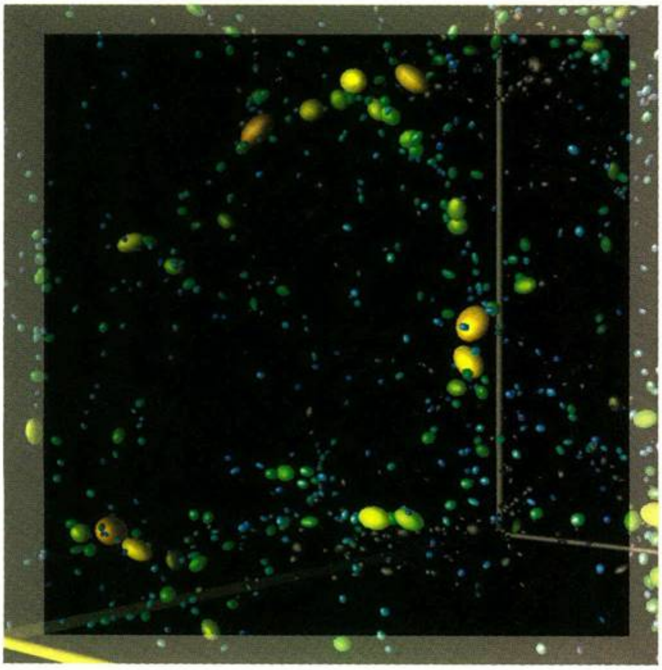
Since quantum mechanics and particle physics are only important on atomic scales or smaller, it wasn't obvious that they could play a role in shaping something as large as a galaxy. A connection between the world of the ultralarge, the outer space of cosmology, and the world of the ultrasmall, the inner space of fundamental particles where the laws of quantum mechanics were important, must have seemed a pretty radical idea.

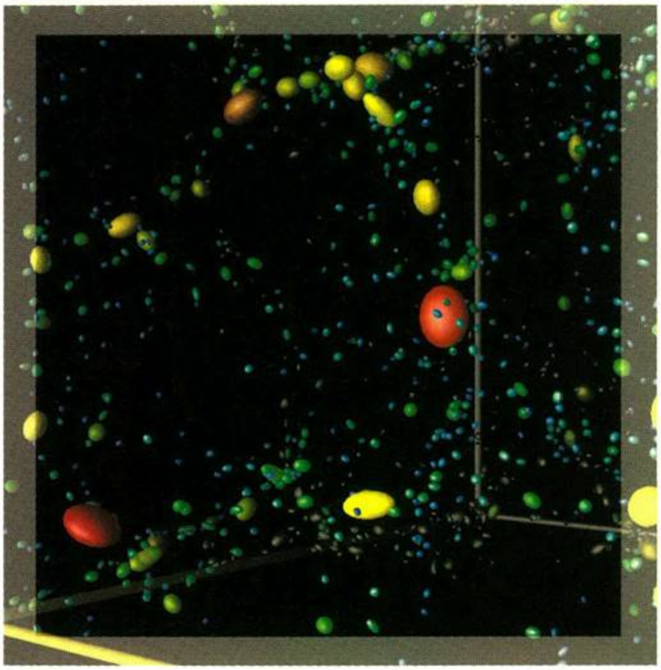
Although some of his fellow revolutionaries might have agreed with Bohr about the importance of quantum mechanics and particle physics in cosmology, I wonder if anyone had an inkling of just how right he was. Once set in motion, revolutions take off in unanticipated directions. The pioneers of the quantum revolution couldn't tell where the revolution would lead. Bohr might have anticipated that in 1947, just 10 years after his lecture, Ralph Alpher, George Gamow, and Robert Herman would study the nuclear physics of the early universe and predict the discovery of a background of microwave radiation. However, even Bohr might have had difficulty imagining that by 1997, 60 years after his Berkeley lecture, conservative cosmologists would believe that everything we see around us — galaxies, stars, planets, people, poodles, pigeons, pond scum, Newt Gingrich (R-Ga.) — started out as quantum fluctuations in the primordial soup of the early universe.

Quantum mechanics and particle physics might seem complicated to non-physicists (and I assure you they sometimes seem complicated to physicists as well), but they may hold the key to the answer of two simple questions about the universe: What's out there, and why is it there?

What's Out There?

On a dark clear night the sky offers much to see. With the unaided eye one can see things in our solar system such as planets, as well as extrasolar objects such as stars. Nearly everything visible by eye resides within our own Milky Way Galaxy. But with a little patience and skill it's possible to find a few extragalactic objects. The Andromeda Galaxy, 2.4 million light-years distant, is visible as a faint nebulous region, and from the Southern Hemisphere two small nearby galaxies (if 170,000 light-years can be considered nearby), the Magellanic Clouds, can also be seen with the unaided eye.





The view through large telescopes reveals the universe beyond the Milky Way. Even with the telescopes of the 19th century, the great British astronomer Sir William Herschel discovered about 2,500 galaxies, and his son, Sir John Herschel, discovered an additional thousand (although neither of the Herschels knew that the objects they discovered were extragalactic). As astronomers built larger telescopes and looked deeper into space, the number of known galaxies grew. Although no one has ever bothered to count, astronomers have identified about four million galaxies. And there are a lot more out there!

Our deepest view into the universe is the Hubble Deep Field. The result of a 10-day exposure of a very small region of the sky by NASA's Hubble Space Telescope, the Hubble Deep Field reveals a universe full of galaxies as far as Hubble's eye can see. If the Space Telescope could take the time to survey the entire sky to the depth of the Deep Field, it would find more than 50 billion galaxies.

Although the largest galaxies contain more than 100 billion stars and stretch across 100,000 light-years or more of space, they aren't the biggest things in the universe. Just as stars are part of galaxies, galaxies are part of even larger structures.

Most galaxies are members of groups containing a few dozen to a hundred galaxies, or even larger assemblages known as clusters, containing several thousand galaxies. Clusters of galaxies are part of even larger associations called superclusters, containing dozens of clusters spread out over 100 million light-years of space. Even superclusters may not be the largest things in the universe. The largest surveys of the universe suggest to some astronomers that galaxies are organized on two-dimensional sheet-like structures, while others believe that galaxies lie along extended one-dimensional filaments. The exact nature of how galaxies are arranged in the universe is still a matter of debate among cosmologists. A picture of the arrangement of galaxies on the largest scales is only now emerging.

Why Is It There?

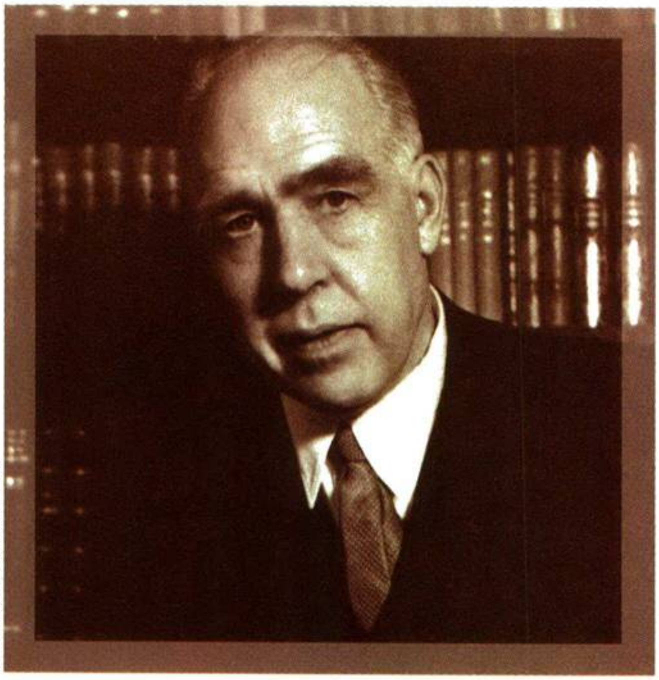
A really good answer to a deep question usually leads to an even deeper question. Once we discover what's in the universe, a deeper question arises: Why is it there? Why are stars arranged into galaxies, galaxies into clusters, clusters into superclusters, and so on?

Part of the answer involves gravity. Everything we see in the universe is the result of gravity. Every time you see a star the imprint of gravity is shining at you. Today we observe new stars forming within giant interstellar gas clouds, such as those found at the center of the Orion Nebula just 1,500 light-years away.

Interstellar clouds are not smooth and uniform; they contain regions where the density of material is larger than in surrounding regions. The dense regions within the clouds are the seeds around which stars grow through the irresistible force of gravity. The dense regions pull in nearby material through the force of gravity, which compresses the material until it becomes hot and dense enough for nuclear reactions to commence and form stars (see "The Story of Starbirth," page 50).

Just as 4.5 billion years ago in our little corner of the Milky Way, gravity started to pull together gas and dust to form our own solar system, about 12 billion years ago, 30,000 years after the Big Bang, a similar process started on a grander scale throughout the universe. For the first 30 millennia after the Bang the universe expanded too rapidly for gravity to fashion structure. Eventually, however, the expansion slowed enough for gravity to begin the long process of pulling together matter to form the universe we see today.

We are quite confident that gravity shaped the universe because astrophysicists can simulate in a matter of days what nature required 12 billion years to accomplish. Starting with the universe as it existed 30,000 years after the Big Bang, large supercomputers can calculate how these "primordial seeds" — small, localized regions of enhanced density — grew to become the giant galaxies, clusters of galaxies, superclusters, walls, and filaments we see throughout the universe.



AIP Emilio Segrè Visual Archives

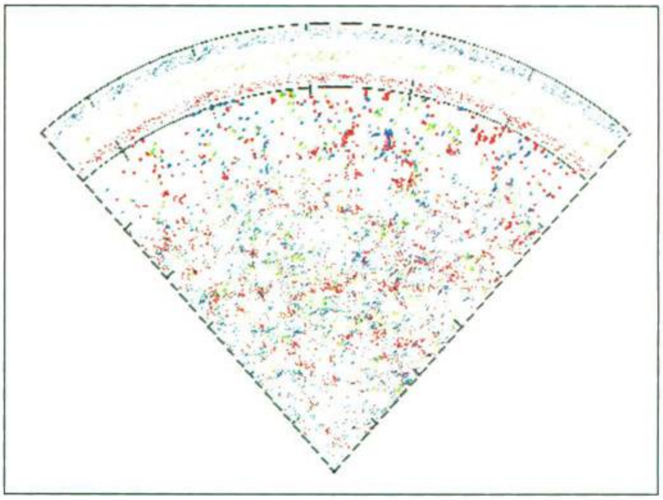
The visionary Danish physicist Niels Bohr was one of the first to realize that a thorough understanding of the submicroscopic realm was necessary before scientists could understand the large-scale structure of the universe.

Gravity alone cannot be the final answer to the question of why matter in the universe has such a rich and varied arrangement. For the force of gravity to pull things together requires small initial seeds where the density is larger than the surrounding regions. Just as though there wouldn't be any seeds to trigger star formation within the Orion Nebula if the gas and dust were perfectly uniform, structure would never have formed if the entire universe was completely uniform. Without primordial seeds in the universe 30,000 years after the Big Bang, gravity would not have been able to shape the universe into the form we now see. A seedless universe would be a pretty boring place to live, because matter would remain perfectly uniform rather than assembling into galaxies, stars, planets, and people.

The pattern of structure in the universe today reflects the pattern of initial seeds. In some sense, the fact that there are things in the universe today is because there were primordial seeds in the universe 30,000 years after the Bang.

Seeds have to be inserted by hand into the computer simulations of the formation of structure. Since the aim of cosmology is to understand the structure of the universe on the basis of physical laws, we just can't end the story by saying structure exists because there were primordial seeds. For a complete answer to the questions of why are there things in the universe, we have to know what planted the primordial seeds. Perhaps Niels Bohr was correct about the deep connection between particle physics and cosmology, because most physicists who study the very early universe believe the primordial seeds were planted by the action of quantum mechanics.

In the microworld of subatomic physics, there is an inherent uncertainty about the positions and energies of particles. According to the uncertainty principle, energy isn't always conserved — it can be violated for a brief period of time. Because quantum mechanics applies to the microworld, only tiny amounts of energy are involved, and the time during which energy is out of balance is exceedingly short.



Stephen Shectman (Carnegie Observatories) and the Las Campanas Redshift Survey Team

Galaxies and galaxy clusters are not evenly distributed, instead they are arranged in vast walls and filaments that stretch across hundreds of millions of light-years of space.

One of the consequences of the uncertainty principle is that a region of seemingly empty space is not really empty, but is a seething froth in which every sort of fundamental particle pops out of empty space for a brief instant before annihilating with its antiparticle and disappearing — these are the so-called quantum fluctuations.

Empty space only looks like a quiet, calm place because we can't see nature operating on submicroscopic scales. In order to see these quantum fluctuations we would have to take a small region of space and blow it up in size. That is not possible in the laboratory, so we have to use a laboratory as large as the entire universe. In the early-universe theory known as inflation, space once exploded so rapidly that the pattern of microscopic quantum fluctuations were blown up to astronomical sizes and frozen into the fabric of space.

Anglo-Australian Observatory/Photography by David Malin

Here we see the core of one of the closest and most massive galaxy clusters, the Virgo Cluster. Galaxy clusters can trace their origin to primordial seeds that were planted shortly after the Big Bang. If the majority of cosmologists are correct, tiny fluctuations in the fabric of space-time planted the primordial seeds.

Much later, the pattern of what once were quantum fluctuations in energy appear as small fluctuations in the mass density of the universe 30,000 years after the Bang. If this theory is correct, then seeds of structure are nothing more than patterns of quantum fluctuations from the inflationary era. In a very real sense, quantum fluctuations would be the origin of everything we see in the universe.

Bohr and his compatriots at the barricades in the quantum revolution had some inkling that their discoveries would shape society. They may have felt that quantum mechanics would reach out from the microworld and leave an imprint on the world around us. But if the latest cosmological theory for the origin of the seeds of structure is correct, then there is a deep and profound connection between the inner space of quantum uncertainty and the outer space of the cosmos. Not many physicists in 1937 dreamed that the laws of quantum mechanics would extend from the microworld and plant the seeds that shaped the entire universe. But maybe Bohr did. ■

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On Becoming the Material World

Ironing out how elements assembled may give us the ultimate understanding of how the universe began.

by James Glanz

THE UNIVERSE WAS NOT CREATED WITH A LIST of ingredients conveniently pasted to its side. Like shoppers considering an unfamiliar brand of pound cake, however, cosmologists would not have minded a bit if the recipe had been so easy to decipher. The atoms in everything that exists today were cooked up from the matter swirling through the universe in the first few minutes after its creation. To understand the significance of the first few minutes, scientists would like to trace the steps from that primordial puree to what we see on our planet, in galaxies, and in the dusky voids between them.

From the cosmological perspective, there is an even greater motive for observing those first ingredients and understanding just how they formed. Their patterns of abundance — how much of one element or isotope existed relative to others — are among the most stringent tests of whether the universe began in a "Big Bang," a homogeneous explosion from an unimaginably hot, dense speck of matter and energy. Such an explosion, which would resemble that of a hydrogen bomb but on an unimagineably grander scale of power, leaves specific residues of the light elements hydrogen, helium, and lithium. If the proper proportions can't be found, then cosmologists would be forced to consider major revisions to their beloved Big Bang.

On the other hand, if the primordial abundances do make sense, then cosmologists get a clue that they may actually understand how the light elements were created. The details of those abundances would also become a kind of probe, retaining subtle imprints of cosmic conditions at much earlier times than any other measurement they can make. Consider just the tenuous dash of deuterium that would have survived the Big Bang. An isotope of hydrogen with one proton and one neutron, deuterium is a fragile nucleus, easily destroyed in collisions with other matter during such an explosion. This simple fact means that the primordial deuterium abundance could be read like ticks on a measuring cup to give the total amount of ordinary matter in the universe: the less deuterium, the more total matter.

That kind of direct measurement remained a topic of theoretical chatter until a few years ago when the 10-meter W. M. Keck Telescope opened its great eye on top of Mauna Kea, a dormant volcano in Hawaii. The Keck's unprecedented light-gathering power has allowed astronomers to see faint, spectral "shadows" of deuterium clouds some 10 billion light-years away, opening a window on the cosmos when it was only a fraction of its present age and such matter still existed in a relatively pristine state. What have the astronomers found? The "headline," as one cosmologist puts it, is that the wisp of deuterium that has turned up does seem roughly consistent with the predictions of big bang nucleosynthesis, the reigning theory of light-element creation.

Unfortunately, no one has come up with that kind of time machine for determining how much helium and lithium got poured with the deuterium into the cosmic pound cake. Instead, researchers have had to work backward from present-day material, which has quite literally been cooked for billions of years in the bellies of stars, where thermonuclear reactions release the energy that makes the stars shine by fusing light elements into heavier ones — such as the carbon atoms on which organic matter is based. But when clever computer algorithms "uncook" the cake to estimate the original abundances of those elements from the present ones, the proportions of helium and lithium isotopes do fall approximately into line with the deuterium values.

dark matter
Lithium
H
D
He
Li
C

Doug Ross

Creating Heavy Elements

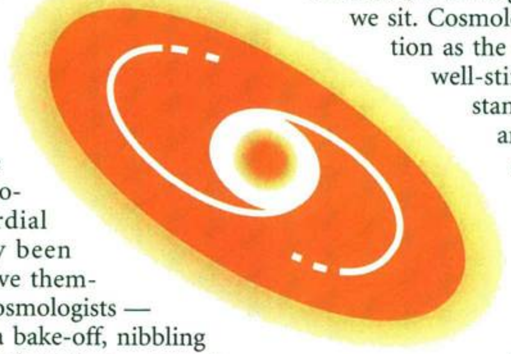
If the creation of elements had ceased after the Big Bang generated the light elements hydrogen, helium, and lithium, the universe would not be the interesting place it is — at least from the human point of view. That's because the fusion furnace of the Big Bang didn't last long enough to cook up the heavier elements needed for life, such as carbon, nitrogen, oxygen, and iron. Nor was there the least chance of producing even heavier elements like gold, iodine, lead, or uranium.

But if there is one thing the stars have in abundance, it's time. The first stars probably formed as gravity caused clouds emerging from the Big Bang to coalesce and collapse into galaxies and stars. As gravity compresses such gases into stars, their cores first become hot enough for hydrogen nuclei to overcome their mutual repulsion and fuse into helium, releasing energy that makes the stars shine. Once the hydrogen is used up in the core, the star compresses a little further and gets hot enough for heliums — with their greater electric repulsion — to fuse into still heavier elements and so on up the line.

That logic plays out at iron, because its tightly bound nucleus means that the star can't derive energy by fusing it with charged particles to make anything heavier. But neutrons, which have no charge, can still slip into the nucleus, and it turns out that stars can go all the way up the elemental stepladder by adding these particles and then spitting out negative charges by a radioactive process called beta decay.

Once a massive star's core becomes too choked with iron, the core becomes too cool to hold up the overlying layers, which catastrophically collapse. The collapsing gases rebound and the whole assemblage explodes as a supernova, spreading heavy elements throughout the galaxy. Those elements might be incorporated into yet another round of star formation or get sidetracked into curious material objects such as human beings.

Mysteriously, the total amount of ordinary or baryonic matter in the universe — the familiar stuff of which people, pencils and planets are made — is extremely low according to the light-element measuring cup. By gauging the force of gravity holding galaxies together and sculpting even larger structures in the sky, many astronomers have decided there has to be more total matter than that. This mismatch is one of the best arguments that some sort of exotic, still-undiscovered, "dark" or nonbaryonic matter is adding its heft to the universe. The search for this extra special ingredient, a kind of chef's secret, has drawn on the mismatch with big bang nucleosynthesis to become an industry in itself.



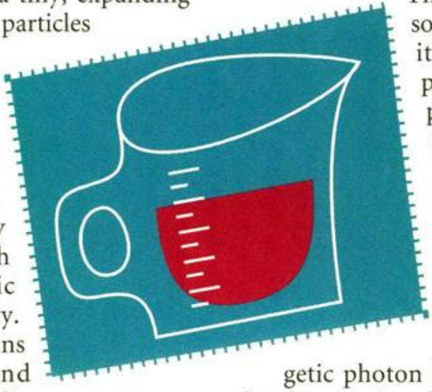
Some further untidiness crops up in persistent, though small, deviations from what's expected for the relative abundances. There is even some controversy over whether the true primordial deuterium abundance has actually been found. However those conflicts resolve themselves, the headline remains that the cosmologists — as ingenious as prying contestants at a bake-off, nibbling on cookies to figure out the competition's recipes — seem to have a handle on what raw materials went into the cosmos. With that achievement under their belts, the cosmologists feel much more confident when they theorize about exactly how those original ingredients were made.

Those theories require only that at some point in its early history, the universe existed as a hot, dense, and fairly smooth puree of matter and energy that followed the laws of physics as we understand them. Without taking into account big bang nucleosynthesis itself, there are two good pieces of evidence to suggest conditions like that probably existed sometime. The first is the universe's present expansion. When we look into space with telescopes, we see that galaxies are flying apart from one another at speeds proportional to the distances separating them, like sparks in a fireworks explosion. Run that observed expansion backward in your mind, and your conclusion is that the cosmos started with a bang, as a hot, dense, compact dollop of matter and energy.

The second piece of evidence is the cosmic background radiation, a homogeneous bath of microwaves in which we sit. Cosmologists interpret the background radiation as the afterglow of a smooth Big Bang. This well-stirred cosmos is convenient for understanding nucleosynthesis, because it nixes any concerns about complicated spatial structure, like marbling in a cake. Big bang nucleosynthesis focuses on this smooth universe from about one second to three minutes after its creation, when it was cool enough for elements to coalesce but not so cool that their abundances were frozen and fixed.

During that time, the mixture's temperature dropped from about 10 billion to below a billion degrees Kelvin (or Celsius). Those temperatures sound like a lot, but when the particles whizzing through such a mixture collide, they carry energies that have been well studied in particle accelerators on Earth. Assuming physical laws haven't changed in the last 10 or 15 billion years, the outcomes of those collisions should be easily predictable.

But first let's back up to the moment of creation and begin with the match that lit the oven. According to one widely studied and highly abstract proposal, that match is called inflation, in which one lucky fluctuation in primordial nothingness found itself in a state called a "false vacuum." This has nothing to do with faulty carpet-cleaning devices but rather is a special kind of nothingness that relentlessly and homogeneously expands. Finally, certain symmetries in the false vacuum shatter, and it becomes a tiny, expanding universe of ordinary vacuum jammed with particles and quanta of light, or photons, at unimaginably high temperatures. At this point the universe is still merely a small fraction of a second old.



Like compressed air expanding out of a nozzle, the universe cools. But for a while, the particles in it are still so hot and tightly packed that protons and neutrons — which will eventually combine to form atomic nuclei — scarcely have their own identity. They smash into lighter or massless cousins like electrons, positrons, neutrinos, and photons and undergo a whole shopping list of reactions that convert one particle into another and back again.

At first, the protons and the slightly heavier neutrons maintain an equal footing and exist in about the same numbers. As the universe cools further though, Einstein's mass-energy equivalence, $E = mc^2$, begins to assert itself, and the extra energy needed to make a neutron in those reactions is not so easy to come by anymore. The protons start to win out at the expense of the neutrons.

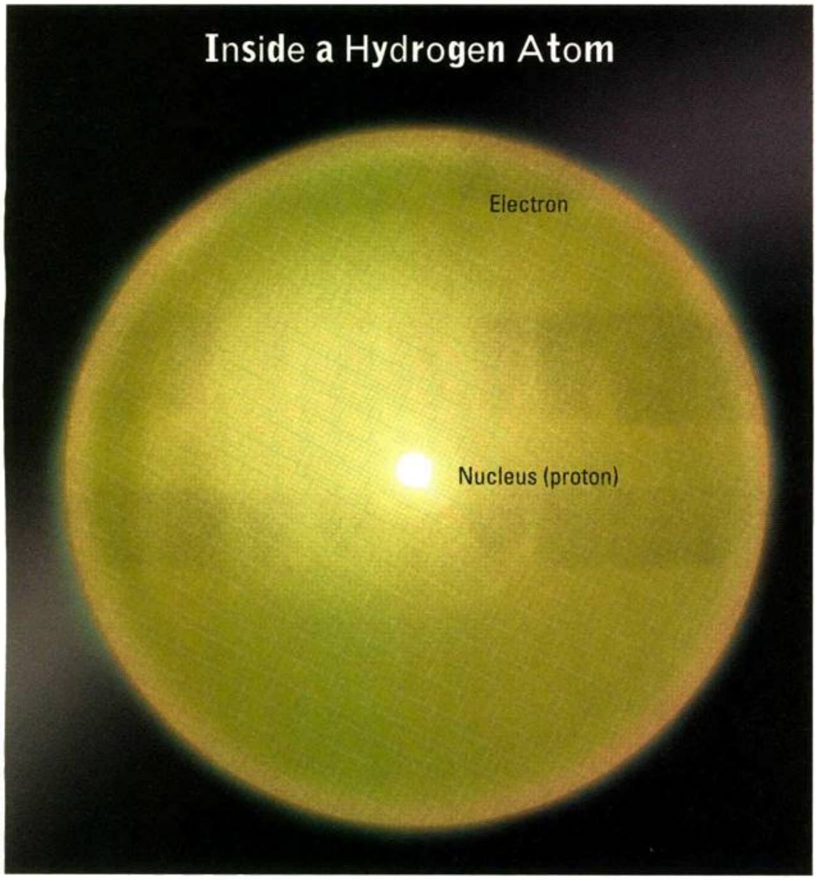
Eventually the cosmic expansion outruns these reactions entirely, so that the proton-to-neutron ratio "freezes out" at a value of six or seven to one. That result already leads to an important prediction: Because simple hydrogen, with a lone proton in its nucleus, is the only light isotope that can gobble up protons without also consuming neutrons, it ought to dominate the universe in the end — as it does, constituting about 75 percent by mass of all ordinary, observable matter.

The isotopes that will ultimately soak up some of those neutrons are deuterium (with its proton and neutron), helium-3 (two protons and one neutron), helium-4 (two protons and two neutrons), and lithium-7 (three protons and four neutrons).

These heavier isotopes can't form right away, because they must all be built up from a series of fusion reactions that begin with deuterium, and deuterium has the lowest binding energy of all the light nuclei. No sooner do a proton and a neutron combine than an energetic photon blasts them apart again. About a second after its creation, however, the universe cools enough that those photons no longer have sufficient energy to break up deuterium. This event suddenly removes a bottleneck in the chain of reactions. The overall effect of these reactions is to funnel nearly all of the available neutrons to helium-4. Why? Its nucleus happens to be the most tightly bound among all the light elements; the fusion reactions are effectively running downhill as they smoosh together protons, neutrons, deuterium, and helium-3 in various ways to make helium-4.

How do these fusion reactions actually take place? As the particles and nuclei come very close during a collision, the short-range "strong" nuclear force kicks in and binds them together. (This need for propinquity means that the colliding nuclei must be moving fast enough to overcome their mutual repulsion, not a problem at these temperatures.) The energy released in these downhill reactions is just what makes a hydrogen bomb explode. Fusion reactions also power the luminous output of stars like the sun — the great difference being that ordinary stars are quiescently burning their fuel and not blowing up. That allows the reactions to run to completion — burning up all traces of deuterium, for example — and provides enough time for much heavier elements to be cooked up by fusion.

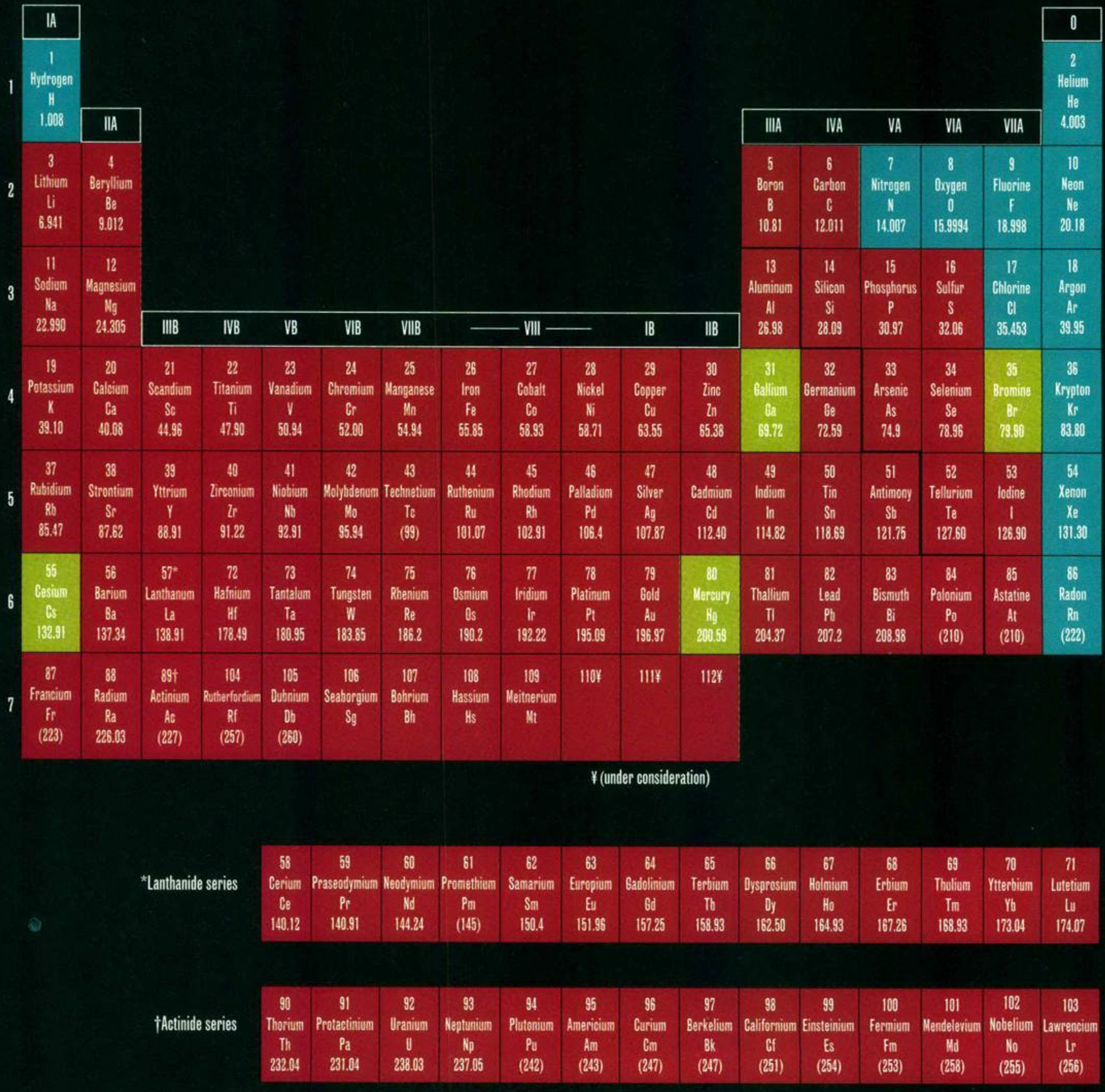
Not so in the Big Bang. But before the universe becomes so cool and rarefied that collisions energetic enough for fusion all but stop happening, most of the neutrons get passed, bucket-brigade fashion, down the string of reactions to helium-4. This fact leads



Astronomy: Lee Vande Visse

When isolated, all atoms might be described as spherical. They assume all sorts of shapes when atoms share electrons, forming so-called covalent molecules. A single hydrogen atom might be described as a sphere like a tennis ball (with a slightly fuzzy surface) caused by the spherical electron shell orbiting the proton, which sits like a pinhead, at the center.

Periodic Table of the Elements



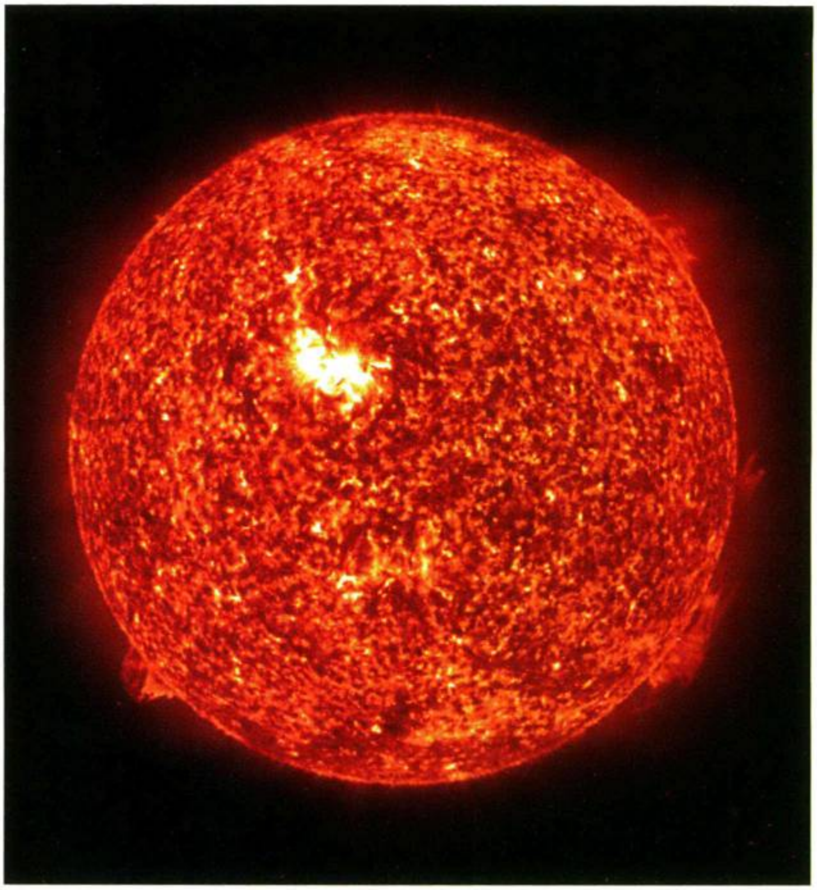
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1	1 Hydrogen H 1.008																	2 Helium He 4.003
2	3 Lithium Li 6.941	4 Beryllium Be 9.012											5 Boron B 10.81	6 Carbon C 12.011	7 Nitrogen N 14.007	8 Oxygen O 15.9994	9 Fluorine F 18.998	10 Neon Ne 20.18
3	11 Sodium Na 22.990	12 Magnesium Mg 24.305											13 Aluminum Al 26.98	14 Silicon Si 28.09	15 Phosphorus P 30.97	16 Sulfur S 32.06	17 Chlorine Cl 35.453	18 Argon Ar 39.95
4	19 Potassium K 39.10	20 Calcium Ca 40.08	21 Scandium Sc 44.96	22 Titanium Ti 47.90	23 Vanadium V 50.94	24 Chromium Cr 52.00	25 Manganese Mn 54.94	26 Iron Fe 55.85	27 Cobalt Co 58.93	28 Nickel Ni 58.71	29 Copper Cu 63.55	30 Zinc Zn 65.38	31 Gallium Ga 69.72	32 Germanium Ge 72.59	33 Arsenic As 74.9	34 Selenium Se 78.96	35 Bromine Br 79.90	36 Krypton Kr 83.80
5	37 Rubidium Rb 85.47	38 Strontium Sr 87.62	39 Yttrium Y 88.91	40 Zirconium Zr 91.22	41 Niobium Nb 92.91	42 Molybdenum Mo 95.94	43 Technetium Tc (99)	44 Ruthenium Ru 101.07	45 Rhodium Rh 102.91	46 Palladium Pd 106.4	47 Silver Ag 107.87	48 Cadmium Cd 112.40	49 Indium In 114.82	50 Tin Sn 118.69	51 Antimony Sb 121.75	52 Tellurium Te 127.60	53 Iodine I 126.90	54 Xenon Xe 131.30
6	55 Cesium Cs 132.91	56 Barium Ba 137.34	57* Lanthanum La 138.91	72 Hafnium Hf 178.49	73 Tantalum Ta 180.95	74 Tungsten W 183.85	75 Rhenium Re 186.2	76 Osmium Os 190.2	77 Iridium Ir 192.22	78 Platinum Pt 195.09	79 Gold Au 196.97	80 Mercury Hg 200.59	81 Thallium Tl 204.37	82 Lead Pb 207.2	83 Bismuth Bi 208.98	84 Polonium Po (210)	85 Astatine At (210)	86 Radon Rn (222)
7	87 Francium Fr (223)	88 Radium Ra 226.03	89† Actinium Ac (227)	104 Rutherfordium Rf (257)	105 Dubnium Db (260)	106 Seaborgium Sg	107 Bohrium Bh	108 Hassium Hs	109 Meitnerium Mt	110¥	111¥	112¥						

¥ (under consideration)

*Lanthanide series	58 Cerium Ce 140.12	59 Praseodymium Pr 140.91	60 Neodymium Nd 144.24	61 Promethium Pm (145)	62 Samarium Sm 150.4	63 Europium Eu 151.96	64 Gadolinium Gd 157.25	65 Terbium Tb 158.93	66 Dysprosium Dy 162.50	67 Holmium Ho 164.93	68 Erbium Er 167.26	69 Thulium Tm 168.93	70 Ytterbium Yb 173.04	71 Lutetium Lu 174.07
†Actinide series	90 Thorium Th 232.04	91 Protactinium Pa 231.04	92 Uranium U 238.03	93 Neptunium Np 237.05	94 Plutonium Pu (242)	95 Americium Am (243)	96 Curium Cm (247)	97 Berkelium Bk (247)	98 Californium Cf (251)	99 Einsteinium Es (254)	100 Fermium Fm (253)	101 Mendelevium Md (258)	102 Nobelium No (255)	103 Lawrencium Lr (256)

Updated to August 1997 by IUPAC and IUPAP at Geneva, Switzerland.

The names, abbreviations, atomic numbers, and atomic weights are given for each element. Elements are color-coded as gases (blue), liquids (green), and solids (red) under normal temperatures. The heavy stairstep line at right divides metallic elements (left of the line) and non-metallic elements (right). Elements become larger moving both downward and rightward from upper left; they become more electrically active moving upward and leftward from bottom right. Atomic weights are listed to four significant figures except for the unstable elements for which the most abundant isotope is listed in parentheses. The values are based on 12C equal to exactly 12. Roman numeral/letter combinations *denote groups (roman) and families* (letters). *Astronomy:* Carole Kramer


SOHO/ESA/NASA

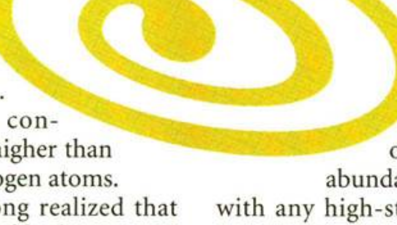
As they fuse light elements into heavier elements, stars create heavy elements such as chromium, manganese, iron, and nickel that are dispersed into the universe.

to a second conclusion, namely, that most of the nonhydrogenic matter in the universe ought to be in the form of helium-4. Indeed, in the neighborhood of the Milky Way, to take a single example, astronomers find about one helium atom for every 12 to 14 hydrogen atoms, which fits that expectation.

Just a scant sprinkle of neutrons should slip past helium to heavier elements, making a few lithium atoms in 10 billion atoms in the early universe. Observers look for that primordial lithium in very old stars whose surfaces have always been too cool for fusion to take place and consume the lithium there. The observers see something between one and two lithiums in 10 billion. Theorists worry that material in the stellar surfaces might still have been simmered in the fusion fires — say, if convection had circulated this material through the star, like boiling soup. That process would have depleted some of the primordial lithium, perhaps explaining the slight shortfall. The predictions are uncertain enough that most cosmologists are happy to be so close.

The quenching of the fusion reactions in the expanding, chilling universe would leave much larger traces of deuterium. As a percentage of the total, exactly how much there is depends critically on the net amount of ordinary matter there is in the universe, or in other words, on the number of protons and neutrons that were originally produced. It's easy to see why: the more matter, the more collisions between nuclei, producing more of those deuterium-consuming fusion reactions. But cosmologists knew they would be in conflict with the helium-4 and lithium values unless they could find something between two and 20 primordial deuterium nuclei for each 100,000 hydrogen nuclei.

For years, cosmologists had to make do with setting lower limits on the primordial deuterium abundance. They reasoned that since all subsequent cooking, such as fusion in the core of stars, would consume this fragile nucleus, the primordial value had to be higher than any measurement we could perform today. The Apollo 11 astronauts, for example, opened a foil shade on the moon, let the solar wind pepper it with particles, and took the shade home for analysis. More recently, the orbiting Hubble Space Telescope scanned the gases of the local interstellar medium for evidence of deuterium. From all such measurements, observers concluded that the primordial value had to be higher than 1.5 deuterium atoms for every 100,000 hydrogen atoms.



And then came Keck. Observers had long realized that extremely distant, almost pristine clouds of hydrogen and deuterium would cast faint shadows when they passed along the line of sight between Earth and the mysterious beacons called quasars. Shining with the light of hundreds of billions of suns, these beacons are even more distant, and the gases would absorb light in characteristic bands of the quasars' spectrum. But only the huge aperture of the Keck could gauge the depth of these dark bands to give an estimate of the relative amounts of hydrogen and deuterium in the clouds.

Over the last several years, the Keck measurements have done more than establish the leading contender for a primordial deuterium abundance — about three per 100,000. More important, just by demonstrating that deuterium probably did exist in reasonable amounts fresh out of the Big Bang, these observations have given a huge boost to the credibility of big bang nucleosynthesis. And the total amount of ordinary matter indicated by this measurement remains a linchpin of the more speculative argument that some sort of exotic dark matter must exist in the universe. The gravity needed to gather together colossal walls of galaxies in the sky and keep individual galaxies from spinning apart implies that there is more mass in the universe than indicated by the deuterium "baryometer," say some cosmologists.

The helium-3, finally, is a tougher observational nut to crack, but its inferred abundances fall broadly in line with the others. As with any high-stakes area of scientific research, disagreements remain, and it is always possible that the whole theoretical soufflé will collapse with further measurement. For now, though, it isn't looking that way. Instead, the light elements are telling a remarkably consistent story, and cosmologists are savoring the closest look they may ever have at creation itself.

James Glanz is a reporter for the journal Science. *He lives in Chicago, one of the largest collections of elements in the United States.*

origins

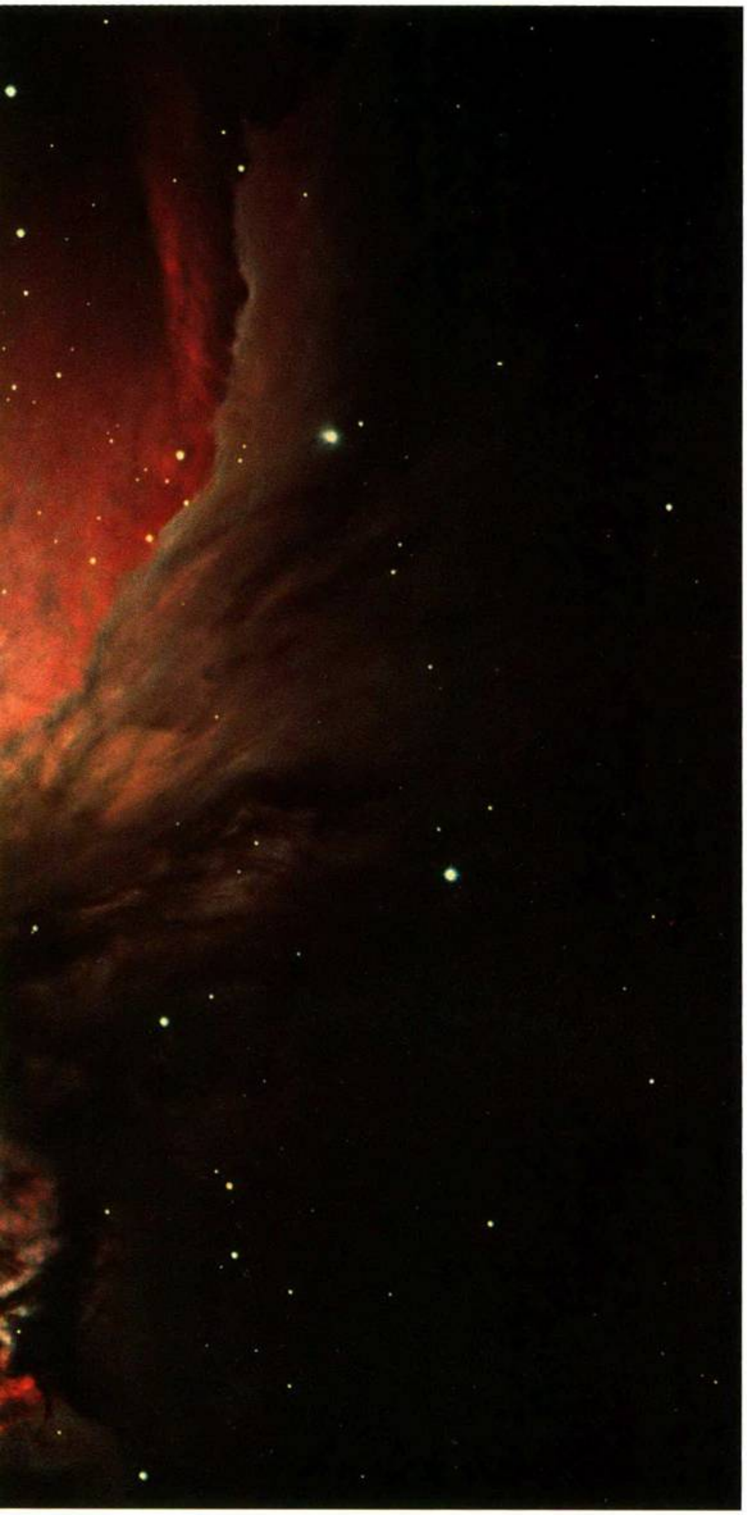
The Story of Star

Anglo-Australian Telescope Board/Photography by David Malin

birth

Out of the cold and empty expanses of interstellar space, gravity gathers matter to form raging infernos of dense gas — stars.

by Robert Naeye



FIVE BILLION YEARS AGO, A DARK, VAST cloud of gas and dust stretched across hundreds of light-years of space. Inside the cloud, temperatures hovered just a few degrees above absolute zero. In one small region nestled deep within the cloud, the turbulent bulk motions of gas molecules bunched enough mass together that gravity could exert its inexorable force, causing part of the cloud to collapse. Or perhaps an external disturbance, such as a passing shock wave from a nearby supernova, induced cloud collapse. Millions of years later, gravity squeezed the densest regions of the shrinking cloud to temperatures and pressures high enough to ignite thermonuclear fires — forming thousands of newborn stars.

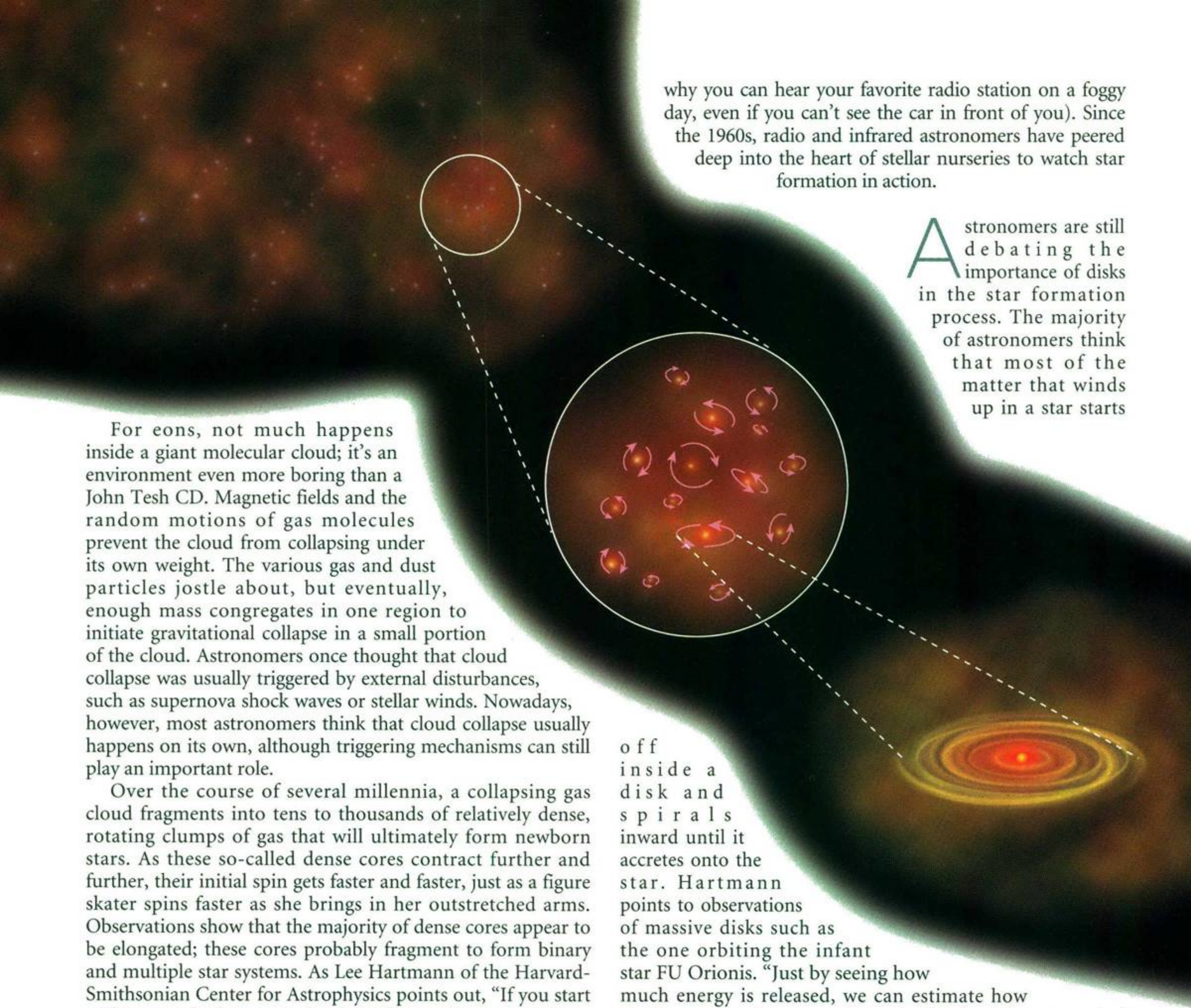
And 4.6 billion years after that, on one of the small chunks of debris left over from the formation of one of those stars, intelligent beings emerged who could ask questions about their origin. Our sun, our solar system, our planet, everyone we know, everyone we love, everything we ever cared about — all of these owe their existence to a collapsing gas cloud some five billion years ago.

Our lives are intimately linked to the stars. Thermonuclear reactions deep inside the sun provide the sustenance for life on Earth. The carbon in our cells, the oxygen we breathe, the calcium in our bones, and the iron in our blood were forged inside stars that passed away billions of years ago. To understand our origins, we must first understand the origin of stars.

The story of star formation is a study in contradictions. It starts with atoms, molecules, and dust particles floating aimlessly in the dark and frigid depths of interstellar space. Out of the cold and empty expanses, gravity brings these scattered particles together to form stars — raging infernos of hot, dense gas that make Dante's conception of hell seem like a pleasant day at the beach.

Over hundreds of millions of years, these gas and dust particles congregate into enormous clouds that can span hundreds of light-years. The two lightest elements — hydrogen and helium — dominate these clouds, accounting for about 92 percent and eight percent of the atoms, respectively. Dust grains account for about one percent of a cloud's total mass. Astronomers call these clouds giant molecular clouds because they also contain trace amounts of molecules such as water, alcohol, ammonia, and various carbon-based organic compounds (the raw ingredients of life). All in all, the clouds contain enough material to form tens of thousands of new stars.

Stars rarely form in isolation; they usually form inside clouds of gas such as the Orion Nebula (M42). The nebula is an active 20-light-year-wide stellar nursery located 1,500 light-years away. Hundreds of stars have already formed here, and many more are continuing to form.



For eons, not much happens inside a giant molecular cloud; it's an environment even more boring than a John Tesh CD. Magnetic fields and the random motions of gas molecules prevent the cloud from collapsing under its own weight. The various gas and dust particles jostle about, but eventually, enough mass congregates in one region to initiate gravitational collapse in a small portion of the cloud. Astronomers once thought that cloud collapse was usually triggered by external disturbances, such as supernova shock waves or stellar winds. Nowadays, however, most astronomers think that cloud collapse usually happens on its own, although triggering mechanisms can still play an important role.

Over the course of several millennia, a collapsing gas cloud fragments into tens to thousands of relatively dense, rotating clumps of gas that will ultimately form newborn stars. As these so-called dense cores contract further and further, their initial spin gets faster and faster, just as a figure skater spins faster as she brings in her outstretched arms. Observations show that the majority of dense cores appear to be elongated; these cores probably fragment to form binary and multiple star systems. As Lee Hartmann of the Harvard-Smithsonian Center for Astrophysics points out, "If you start with a stretched out gas cloud, you're much more likely to get two things out of it than if you start with just one that's centrally concentrated." Because most stars reside in multiple star systems, it's possible — perhaps likely — that the sun formed in a multiple star system and was later gravitationally kicked out after a close encounter with one of the other stars.

The center of a dense core collapses quickly to form a protostar. Due to the rapid spin, the rest of the dense core flattens into a disk. Friction causes material in these maelstroms to spiral inward, feeding a veritable feast of material to the ravenous protostar at the center of the disk. Astronomers believe that planets coalesce inside these disks.

Protostars don't yet have sufficient heat and pressure in their cores to ignite hydrogen fusion reactions, the main energy source of stars. Nevertheless, protostars radiate brightly in infrared light as they convert the energy of gravitational contraction into heat. At this stage, protostars are many times larger than the sun, even if they contain less mass.

Until recently, the cloud-to-protostar process was hidden from view. The dark shroud of gas and dust surrounding a forming star blocks astronomers' view in visible light. But radio waves and infrared light penetrate the obscuring veil (which is why you can hear your favorite radio station on a foggy day, even if you can't see the car in front of you). Since the 1960s, radio and infrared astronomers have peered deep into the heart of stellar nurseries to watch star formation in action.

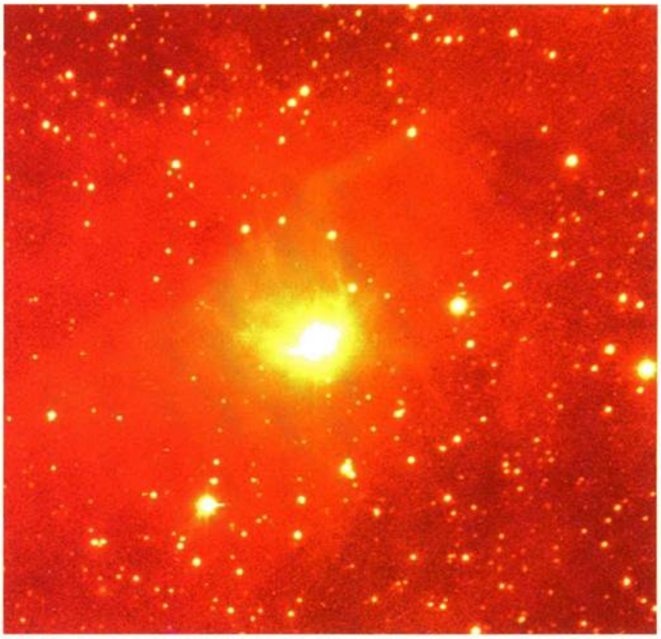
Astronomers are still debating the importance of disks in the star formation process. The majority of astronomers think that most of the matter that winds up in a star starts off inside a disk and spirals inward until it accretes onto the star. Hartmann points to observations of massive disks such as the one orbiting the infant star FU Orionis. "Just by seeing how much energy is released, we can estimate how much mass has been accreted onto the star. The amount of mass that has been accreted onto the star in just the last 50 years is a hundredth of a solar mass (about 10 Jupiter masses). It's hard to imagine that the disk isn't a lot more massive than what's been accreted in the last 50 years. Disk accretion must be an important process in star formation."

Yale University astronomer Richard Larson, who admits his view "is not the standard textbook story," thinks disks play a peripheral role. He points to observations that show that dense cores don't spin very fast, probably because of the braking influence of magnetic fields threading the clouds. As a result, he thinks most of a star's mass comes directly from a collapsing cloud. "Actually, there's not much evidence that a large amount of mass goes through a disk stage," he says. "Lots of young stars have disks, but the disks only have one percent or less of the sun's mass. I think disks are a minor part of the story. Disks may form from the leftover dreg that didn't fall into a star."

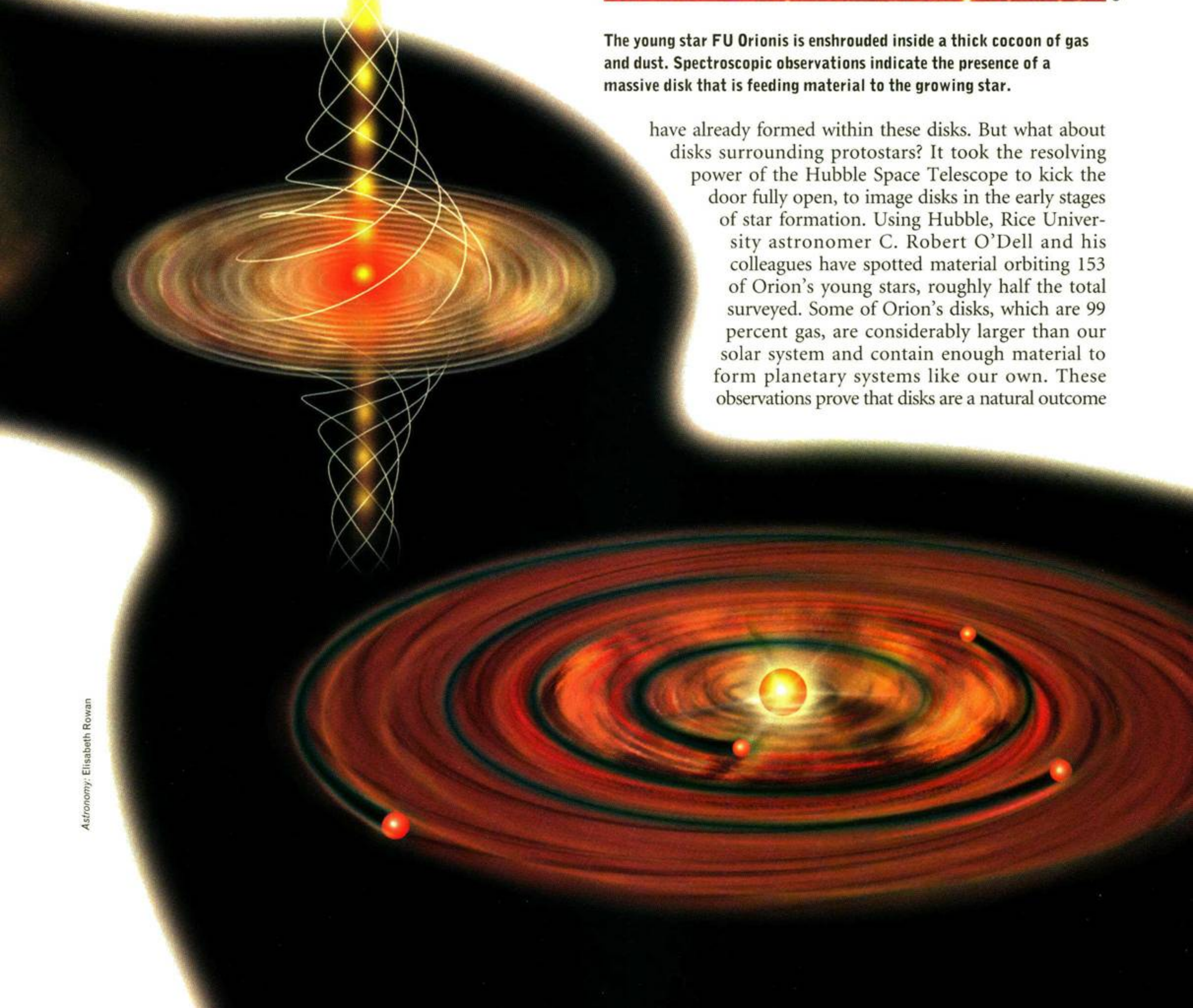
No matter what role disks play, their mere existence provides a perfect example of theorists getting it right. For decades, astronomers suspected disks were out there, but they didn't have the instrumentation to actually detect them. All of that changed in 1983 when astronomers Bradford Smith and Rich Terrile discovered a smoking gun: a disk surrounding the star Beta Pictoris, about 50 light-years away. Beta Pictoris is a young star, roughly 50 million years old, but it's old enough to sustain hydrogen fusion reactions in its core. It is thus a bona fide star rather than a protostar. Its disk, which contains mostly dust and virtually no gas, has little mass and is probably a remnant disk that's being regenerated by colliding comets and planetesimals. Most of the gas that once orbited Beta Pictoris was swept up by planets or blown away by the star's wind and heat.

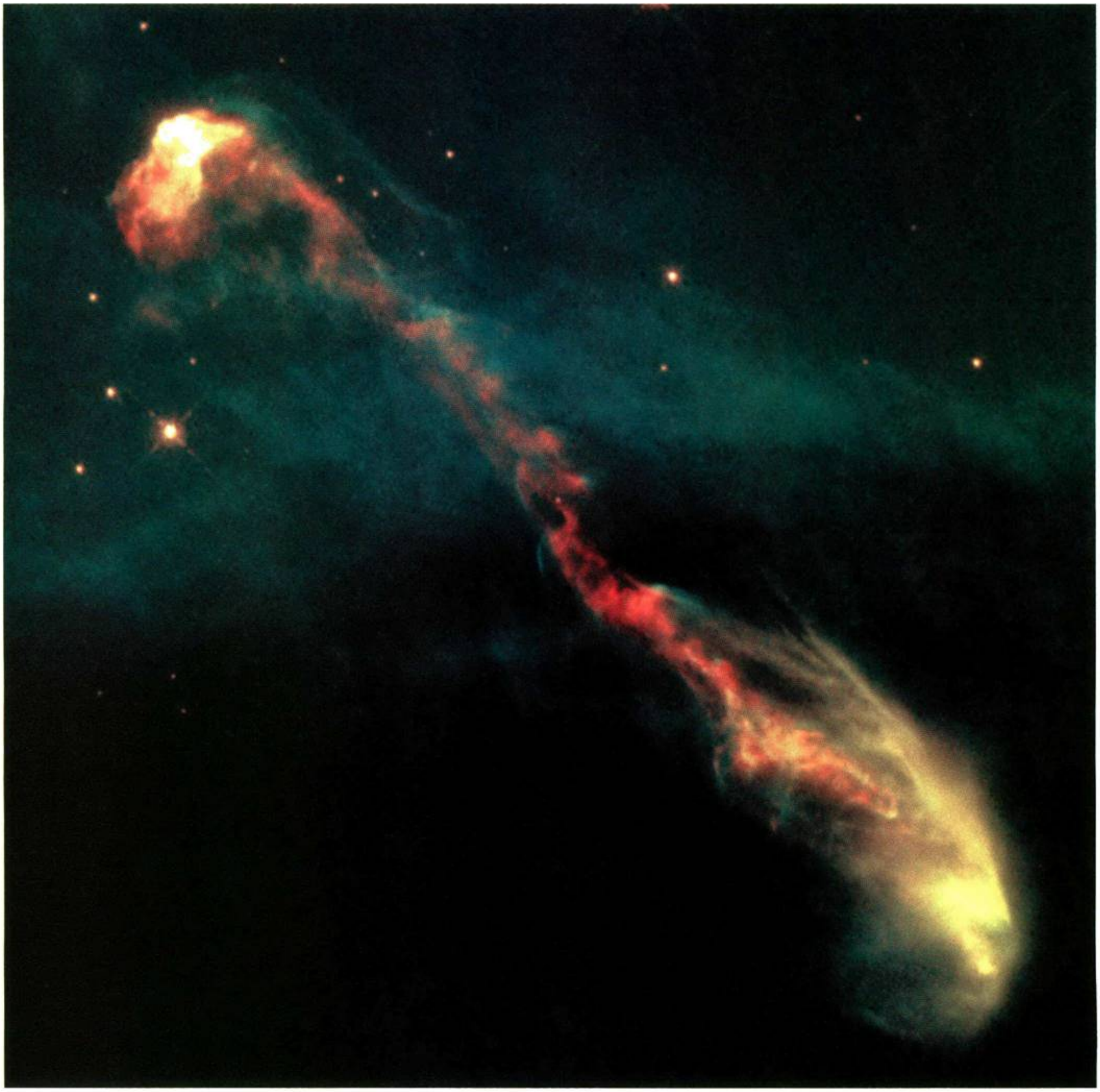
Shortly after the Beta Pictoris discovery, astronomers using the Infrared Astronomical Satellite (IRAS) discovered similar disks surrounding several other young stars, including Vega and Fomalhaut. IRAS had a relatively easy time spotting these disks because the dust particles in the disks absorb the stars' visible light and then reradiate the energy in the infrared.

The Beta Pictoris, Vega, and Fomalhaut disks are older disks which surround young yet mature stars. Planets may have already formed within these disks. But what about disks surrounding protostars? It took the resolving power of the Hubble Space Telescope to kick the door fully open, to image disks in the early stages of star formation. Using Hubble, Rice University astronomer C. Robert O'Dell and his colleagues have spotted material orbiting 153 of Orion's young stars, roughly half the total surveyed. Some of Orion's disks, which are 99 percent gas, are considerably larger than our solar system and contain enough material to form planetary systems like our own. These observations prove that disks are a natural outcome


Cesar Briceño/Whipple Observatory

The young star FU Orionis is enshrouded inside a thick cocoon of gas and dust. Spectroscopic observations indicate the presence of a massive disk that is feeding material to the growing star.


Astronomy: Elisabeth Rowan



Jon Morse (University of Colorado), et al., and NASA

of starbirth and all but clinch the longstanding idea that planet formation represents the final stages of star formation.

While astronomers continue to dispute the specific role that disks play in star formation, they agree that the infall of material onto the stars powers spectacular jets of hot, ionized gas that can stretch across tens of light-years of space. The jets shoot away in opposite directions along the star's rotational axis, a direction perpendicular to the disk, and can propel trillions of tons of gas into space each day. Many such jets are clumpy, meaning material is being shot out in machine-gun-like fashion every 20 to 50 years. Because jets appear to be intimately linked to accretion, the clumps are telling astronomers that disks dump material onto stars in spurts. Although the details remain shrouded in mystery, theorists have developed a model to explain the jets. Magnetic field lines of force threading a rotating disk become twisted, forming helix-shaped cones not unlike stripes on barber shop poles. These twisted magnetic field lines funnel disk material into jets, which remain tightly collimated like laser beams across light-years of space.

Hypersonic jets of ionized gas are commonly found shooting away from newborn stars. This jet (imaged by the Hubble Space Telescope) spans half a light-year, equivalent to three trillion miles. The newborn star is embedded in its mother cloud at the lower right. The jet's twisting helix shape may be due to the gravity of a binary companion.

Hubble Space Telescope images show that jets originate very close to their host stars, and material within the jets has been clocked at more than 500,000 miles per hour. When fast-moving jet material slams into the surrounding interstellar gas, the collision generates a bow shock not unlike that of a speedboat skimming across a lake (but on a much larger scale, of course). The violent collision heats the stationary gas, forming glowing shock regions known as Herbig-Haro objects, after the astronomers George Herbig and Guillermo Haro who discovered them in the 1950s.

The jets also seem to be driving vast outflows of cold gas away from the star. These outflows are much slower than the jets (20,000 to 50,000 miles per hour), but they can contain more mass than the stars themselves. The jets are nested inside these vast outflows. The exact connection between the jets and outflows remains unclear.

As protostars continue to shrink under gravity's relentless clutch, but before they begin fusing hydrogen into helium, they go through a phase named after the prototype star T Tauri. These adolescent stars vary wildly in energy output, and they shed mass in vast winds at a rate one million times that of the solar wind (they can lose several lunar masses per year). T Tauri stars rotate rapidly, which produces a dynamo effect that generates powerful magnetic fields responsible for starspots and flares that dwarf their solar counterparts. By the time a star has reached the T Tauri phase, however, most of the disk's mass has already accreted onto the central star or been blown out of the system by the star's wind, so the rate of mass infall from the disk has slowed to a crawl. It's during this phase, which can last several million years, that planets can assemble inside the disk.

Ultimately, a T Tauri star contracts to a density where temperatures and pressures in the center ignite a thermonuclear spark — hydrogen begins to fuse into helium — a star is born. For hydrogen fusion to take place, temperatures must exceed 10 million kelvins (18 million degrees F). Energy flowing outward from the core creates a gas pressure that counterbalances the inward pull of gravity: The star is in a state of equilibrium. It is ready to assume its rightful place on the main sequence, meaning it has entered the hydrogen-fusing phase in which it will spend most of its life. By the time hydrogen fusion gets underway, stars have long since stopped accreting matter from their disks.

Because gravity works faster when there's more available mass, the formation process from start to finish takes a few million years for high-mass stars, roughly 40 million years for stars like the sun, and hundreds of millions of years for the lowest mass stars. Astronomers still don't fully understand why the star formation process gives rise to the particular distribution of stellar masses, in which stars with 0.5 to one solar mass are the most abundant, while the highest and lowest mass stars are relatively uncommon. "It's a perennial question that's been around ever since I started 30 years ago, and it's never gone away," says Larson.

Astronomers have a particularly difficult time explaining the formation of extremely high-mass stars, adds Larson, because the radiation pressure of these exceptionally luminous stars should blow away the surrounding gas before it can accrete onto the stars. Larson speculates that stellar heavyweights may result from stellar mergers, as evidenced by observations showing that high-mass stars always form in the densest regions of the most massive clouds.

Take the Orion Nebula, for example. Hundreds of stars are forming inside this 20-light-year-wide hot spot at the edge of a giant molecular cloud. The four most massive and energetic stars in the nebula, known as the Trapezium, lie near the center and presumably formed where the gas density was highest.

Vince and Maggie Farnsworth

Open star clusters such as the Pleiades (M45) are a typical end result of the star formation process.

Newborn stars — particularly the most massive ones — are *les enfants terribles* of the cosmos. They blast away at their surroundings with torrents of ultraviolet light and powerful stellar winds, literally destroying their mother clouds in an ultimate act of cosmic matricide. Some of the Hubble Space Telescope's most dramatic images show stellar nurseries such as the Eagle and Lagoon nebulae being evaporated by the ultraviolet flux of newborn stars.

High-mass stars such as those in the Trapezium pump out so much light that they ionize and illuminate their surrounding nebulae, enabling astronomers to easily spot pockets of star formation in faraway galaxies. These stellar beacons live out their lives in a few million years (a blink of the eye on the cosmic timescale) and explode as supernovae before wandering far from their birthplaces. These stars and their associated parent clouds define the arms of spiral galaxies — where the most active star formation takes place. Stellar winds from high-mass stars and supernova shock waves can trigger collapse in neighboring portions of a giant molecular cloud, so one generation of stars can help produce the next.

Eventually, the combined winds and radiation from hundreds or thousands of newborn stars completely blow away their surrounding cocoon of gas. What's left is often an open cluster, a loosely bound collection of several hundred to several thousand stars. The Pleiades is the most beloved example of an open cluster. Open clusters eventually break apart as their constituent stars go their separate ways.

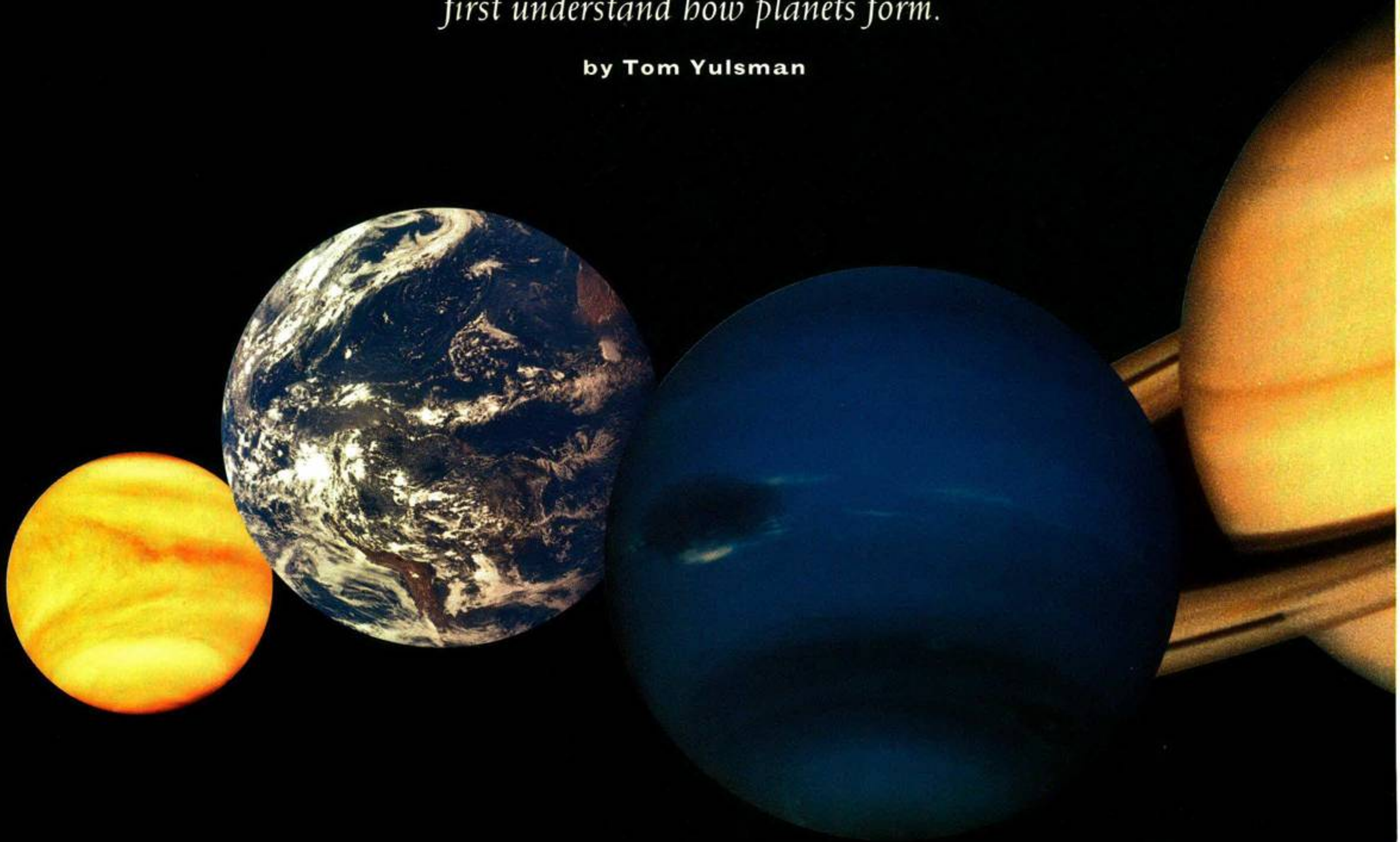
While stars themselves are monstrous entities, by making stars, the universe makes life possible. And by making life possible, the universe brings about the capacity for self awareness. But before it can do that, the universe needs to make little rocky and gaseous things that go around stars — planets. ■

Astronomy *associate editor Robert Naeye (rnaeye@astronomy.com) is author of the book* Through the Eyes of Hubble: The Birth, Life, and Violent Death of Stars *(Kalmbach Publishing Co., 1998).*

From Pebbles

To know whether we're alone in the universe, we must first understand how planets form.

by Tom Yulsman

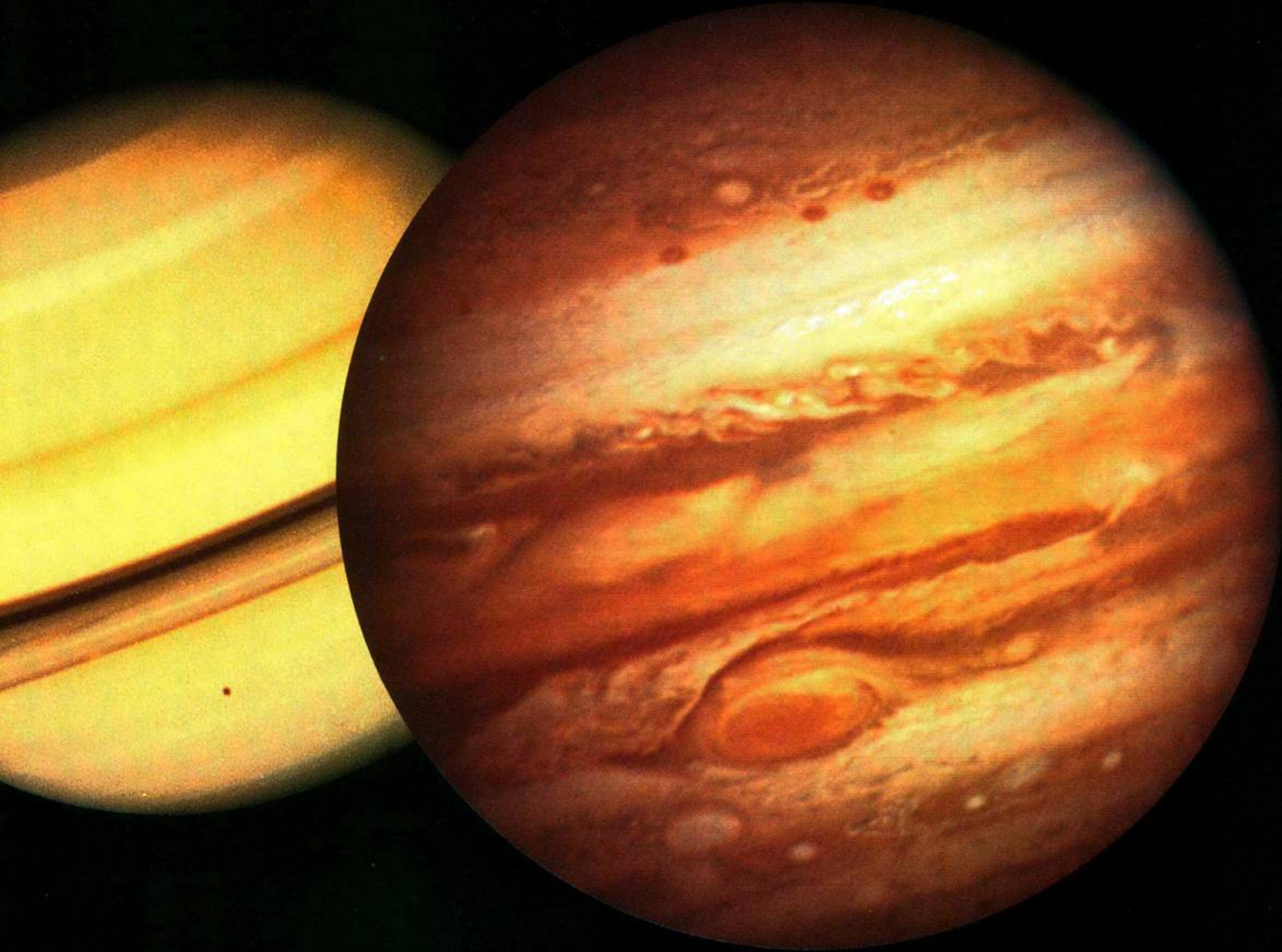


Until just a little more than two years ago, scientists trying to explain the origin of planets had only our own solar system to go on — a dust mote of information compared to the universe as a whole.

All photos above: NASA

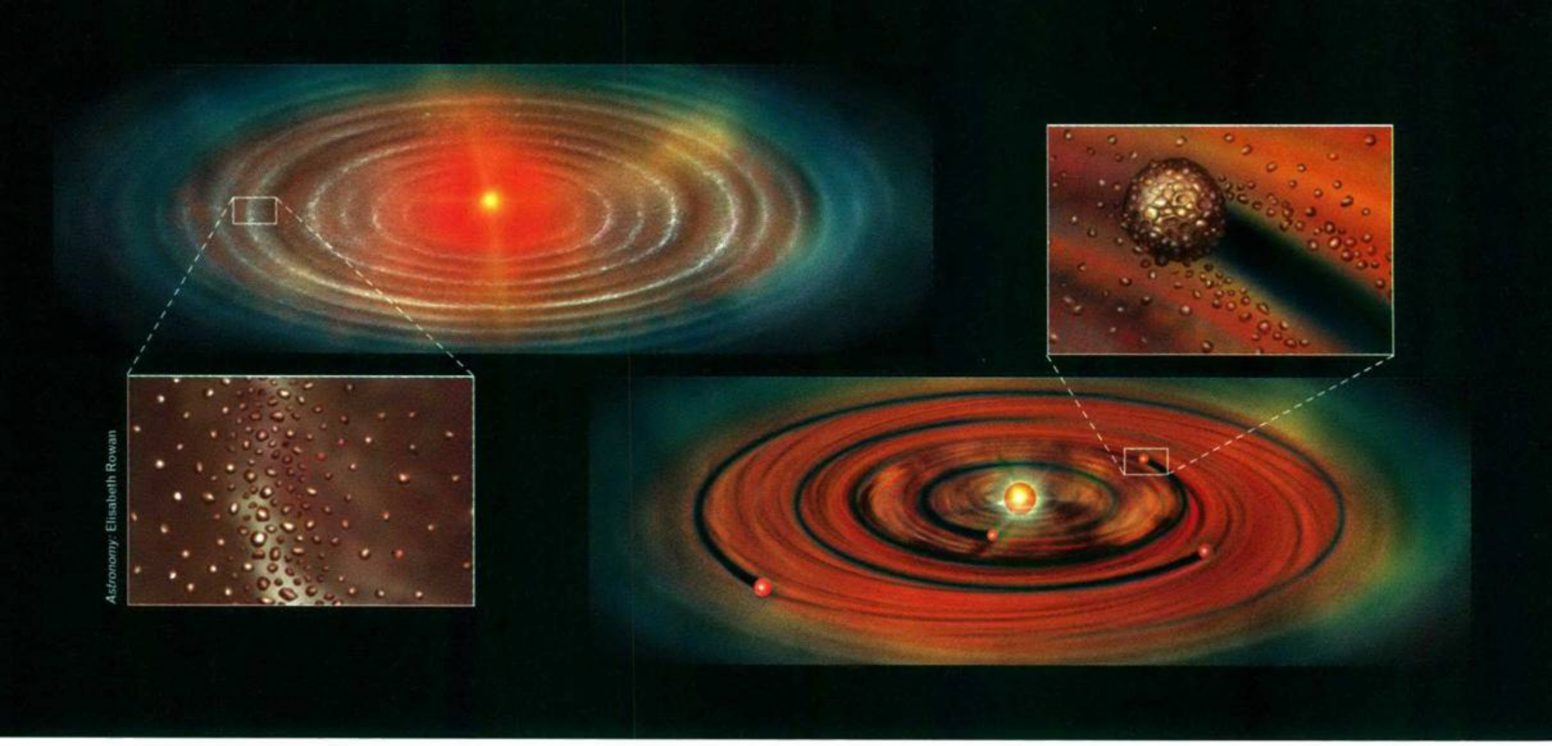
But then came the discovery in 1995 of what appeared to be a Jupiter-like planet circling the sun-like star 51 Pegasi. The relationship between parent star and child was unlike anything our own solar system had led astronomers to expect. The extrasolar (meaning outside our solar system) planet

to Planets



appears to be at least 150 times more massive than Earth. Yet remarkably, it orbits 20 times more closely to its parent than Earth circles the sun.

Since then, scientists have discovered what appear to be at least nine additional extrasolar planets. The orbits of five, including 51 Pegasi's planet, are far smaller than the standard theory of planetary formation deems possible. Scientists have dubbed the quintet "hot Jupiters" because they are similar in mass to the largest planet in our solar system and are so close to their stars that they should be quite toasty.



Astronomy: Elisabeth Rowan

So here was a discovery of solar systems so radically different from the one we inhabit that scientists could no longer consider ours the only model in the universe. Suddenly, they had a whole lot more to go on than our own solar system — and a lot of explaining to do.

But hot Jupiters have not forced scientists to throw out the theoretical blueprint that explains how to build a solar system. That blueprint was drawn up by the German philosopher Immanuel Kant in 1755 (just three years after Benjamin Franklin proved that lightning was made of electricity). Later codified by the French mathematician Pierre-Simon de Laplace, it still holds true today as the overarching plan of planetary origins. But within that big picture, scientists must now add new details.

And those details may just help them answer one of the most vexing questions animating research in astronomy today: Are we earthlings alone or are we just one tiny clan in a vastly larger cosmic community?

Kant's 1755 work, *Universal Natural History and Theories of the Heavens*, includes a simple yet enduring description of how planets form in what today are called protoplanetary disks: ". . . we see a region of space extending from the centre of the sun to unknown distances, contained between two planes not far distant from each other," Kant wrote. Within this disk, "the attraction of the elementary matters for each other" draws particles together to form larger and larger objects, eventually creating planets.

In 1983, observations by astronomers Bradford Smith and Rich Terrile revealed a rotating disk of dust around the young star Beta Pictoris, about 50 light-years away — the first confirmation of a major part of Kant's hypothesis. Since then, protoplanetary disks have become a common sight through the Hubble Space Telescope.

"The Kant-Laplace hypothesis forms the basis of all modern work on planet formation," notes Alan Boss, an astrophysicist at the Carnegie Institution of Washington. "It has been spectacularly proven through astronomical observations that these suspected protoplanetary disks actually do exist. We need only to detect the presence of protoplanets in these disks before finishing the proof."

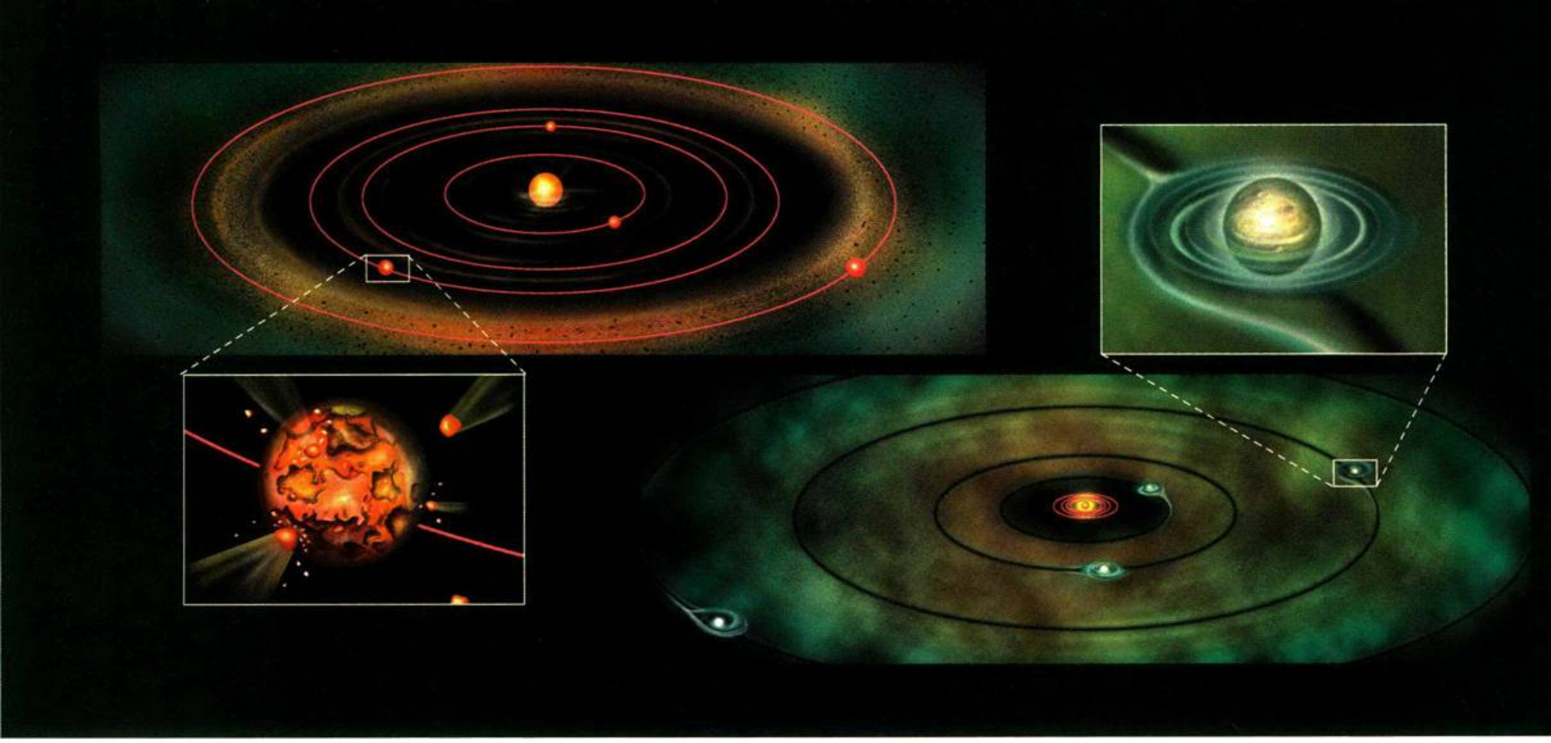
But how do these planetary wombs form and then give birth to planets? As scientists currently understand it, the process starts when part of a rotating interstellar cloud consisting mostly of gas (a "molecular cloud") begins collapsing in on itself. According to Jack Lissauer, an expert in planet formation at NASA's Ames Research Center in California, the material in the cloud cannot simply collapse symmetrically into a sphere; the cloud's rotation creates angular momentum, which prevents that.

Instead, the angular momentum causes some of the infalling material to flatten into a disk that whirls around the waist of a young star at the center. This disk, like the star, consists primarily of the hydrogen and helium gas that made up the bulk of the molecular cloud, with perhaps one to two percent heavier elements.

Relatively close to the star, the disk is cool enough for some of the material to exist in solid form — either tiny particles of interstellar dust or other solids that have condensed into grains from the disk's gas. According to Bill Ward, a planet formation expert at NASA's Jet Propulsion Laboratory, electrostatic forces can make these grains stick together. (This is the force that causes your clothing to cling when you empty the drier.) The grains tend to settle into the mid-plane of the disk and eventually grow into pebble-sized objects.

But it's still not entirely clear how a bunch of pebbles manage to collide, stick together, and form kilometer-wide planetesimals — the "great big dirt balls," as Ward describes them, that are the progenitors of planets.

Electrostatic forces operate at the surface of an object. So the greater the surface area of nearby objects, the greater the likelihood that this force can pull them together. But there's another part to the equation: mass. Because the masses of neighboring pebbles are high compared to their surface areas, the electrostatic attraction between them cannot easily overcome their inertia. Consequently, the pebbles don't readily move together, let alone stick. In addition, a pebble is not massive enough for its gravitational field to attract and hold on to other pebbles. So pebbles are in limbo — they are too



Inner planets gradually build up as particles and pebbles coalesce into larger bodies. In the final stages of planet formation (far right), outer planets sweep up huge amounts to become gas giants.

massive for one force to get them to stick, yet they're not massive enough for another to work either.

There are a number of hypotheses that attempt to pull pebbles out of limbo, but each has its own problem. In one promising idea Ward described recently at a NASA conference on cosmic origins, pebbles of similar size become packed together at stagnant points in the turbulent flow of material in the disk, helping them to coalesce into larger and larger objects. The problem is that computer modeling shows this process can build beachball-size objects, not planetesimals. "The mystery is still as cloudy as ever," Ward concluded.

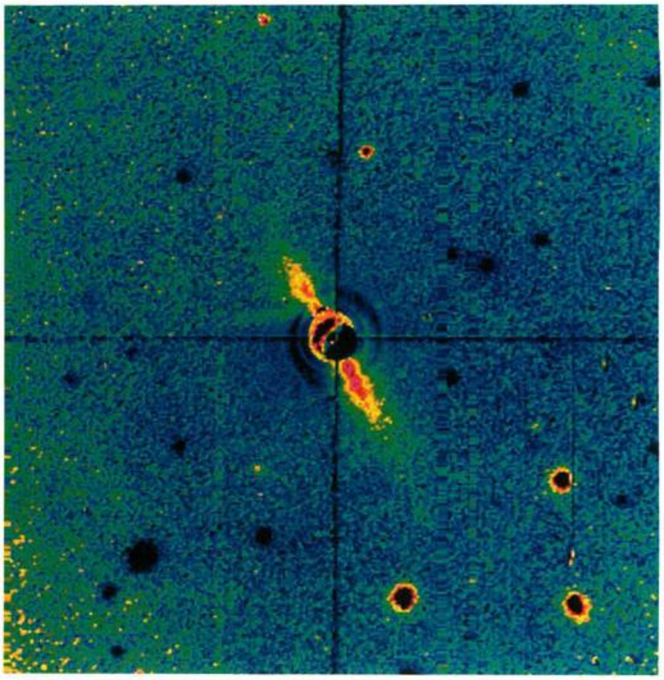
"So somehow, maybe better living through chemistry, planetesimals form," Lissauer jokes. And once kilometer-size planetesimals form, the next part is much easier to explain. Larger planetesimals in the evolving disk are massive enough for their gravity to hold onto almost all objects they collide with, and so they grow larger. Meanwhile, smaller planetesimals are either sucked up by the bigger ones or are stomped to dust in collisions.

In this way, Lissauer says, "the rich get richer and the poor get poorer." And calculations show that the rich accumulate their wealth faster than the likes of Bill Gates, growing much faster and fatter than the rest of the swarm in a process known as runaway accretion.

Through the runaway process, a planetesimal can grow to the size of the moon on the order of 100,000 years. At this point, the object has sucked up most of the material within its feeding zone, so the runaway winds down dramatically. The lunar-size ball of rock does keep growing by accretion, just at a slower pace.

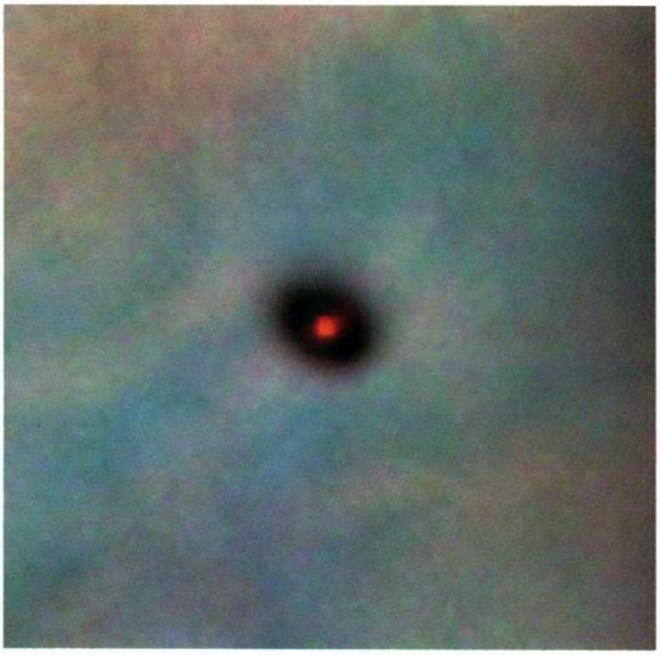
Slower, but hardly sedate. Moon-size objects collide cataclysmically, adding their bulk together until planets with masses on the order of Earth's are formed. At this stage in the planetary construction process, the job is nearly complete for rocky terrestrial planets such as Mercury, Venus, Earth, and Mars. All that remains to be added are the peculiar characteristics that define an individual planet. With fortuitous positioning around the star, a terrestrial planet may acquire an atmosphere with just the right constituents in just the right amounts to insure the cosmic equivalent of a Sun Belt climate — one that can allow liquid water, a prerequisite for life, to exist.

But for giant planets such as Jupiter and Saturn, construction is far from complete. These behemoths consist of a rock and ice core containing as much as 10 or 15 Earth-masses enveloped by massive atmospheres. The core can be built by



University of Arizona/JPL

Planets may have already formed inside this dusty disk, which orbits the young star Beta Pictoris. This disk is probably a remnant of the planet formation process.



runaway accretion, but it must then acquire a huge envelope of gas. Just how that happens remains an open question.

"We still don't have an acceptable model for giant planet formation," says Boss. "And without that, it's hard to say that we understand the planet-formation process in its entirety."

Construction of a gas giant must be completed before the young star's heat and radiation blow away the disk's gas. Otherwise, the growing planet will run out of raw material. Scientists haven't come even close to nailing down how long that takes. "Based on observations of disks around young stars," Lissauer notes, "the total time available is between one million and 10 million years."

But whatever number in that range is right, that's a startlingly brief amount of time on the cosmic time scale to do something as profound as build a giant gaseous planet. One way to beat the clock is through another runaway process.

At first, the gravitational pull of the rock and ice core would gather gas slowly. But modeling shows that as the planet becomes steadily more massive, its increasing gravitational field draws in gas at an ever-increasing rate, leading to runaway accretion of gas. According to this model, the entire process — from the first dust grains that stick together to the completion of the giant gas atmosphere — can take eight million years.

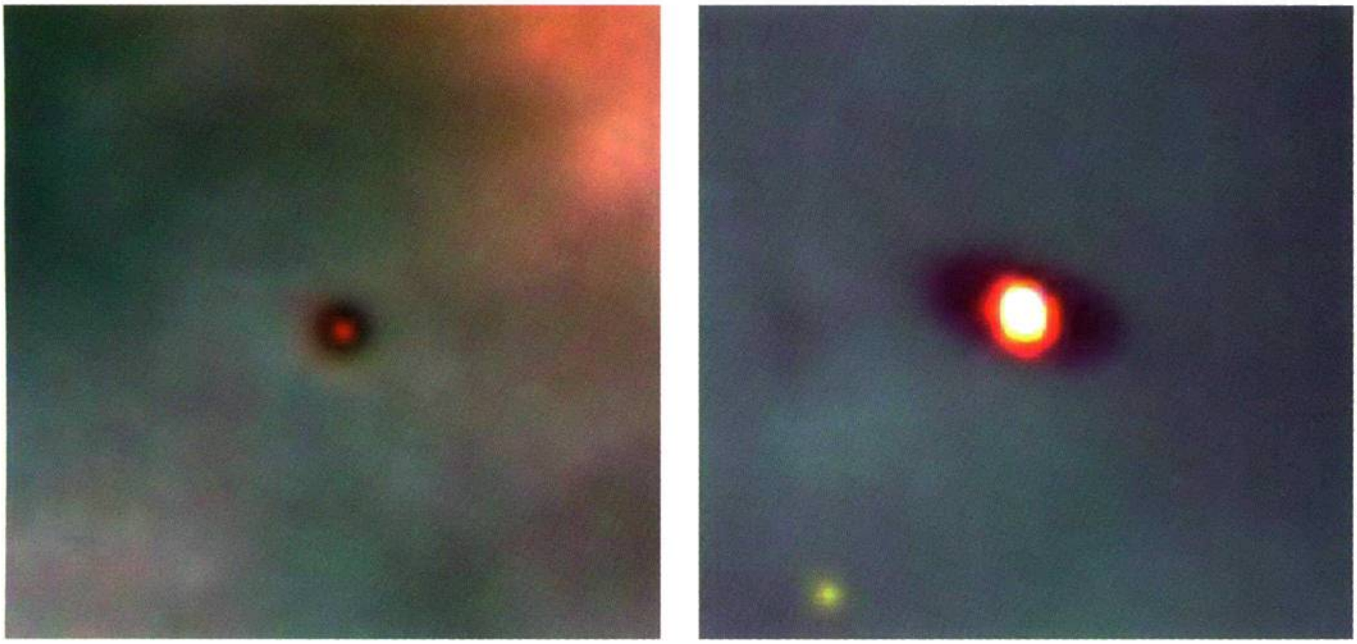
Lissauer hypothesizes that in our own solar system, Jupiter and Saturn experienced the full gas runaway effect. Uranus and Neptune formed farther out from the sun, where orbital periods were longer and there was less material, and thus accretion proceeded less rapidly. Consequently, the gas disappeared before the runaway could occur, explaining why these planets are smaller. At the far, cold reaches of the disk, planetesimals grew very slowly due to the long orbital periods, explaining why Pluto and the other objects beyond Neptune lack substantial atmospheres.

Meanwhile, the terrestrial planets were too close to the sun to form massive gas atmospheres. The problem: The small circumference of the inner disk meant that there was not enough material to build a massive planet before the disk dissipated. Also, the inner regions were "as hot as a blast furnace," Boss says — way too hot for hydrogen and oxygen to form water ice, thought to be a key ingredient in building the core of a massive planet. As a result, these cores didn't have enough mass to grab the surrounding gas. Farther out, it was cold enough for ice to form, providing the accreting core of a gaseous planet much more solid material with which to grow especially large, especially quickly.

Boss has proposed another way of making giant planets before a disk's gas disappears. In the previous two-step models, gaseous planets such as Jupiter initially form around a rock and ice core. But in Boss's new computer models, gaseous planets form directly from clumps of gas inside a disk. "When the disk is young and fairly massive, with about 10 percent of the sun's mass, it may spontaneously break up into giant protoplanets because of the self-gravity of clumps of gas in the disk," says Boss. Later, dust grains inside the planet would settle to the center and form the core. If Boss's model is correct, the cores of Jupiter and Saturn have only one-tenth to one-third as much mass as once believed, and gas giants can form in only a few hundred thousand years rather than a few million years. Still, this single-step method only works in the cool regions of a disk, far from the star.

This is where the limits of the standard theory of planet formation are reached, because it just can't explain how a Jupiter-size planet can form within cosmic spitting distance of a star. Scientists haven't given up on trying to find a way to build Jupiter-size planets close in, but at the moment, hot Jupiters simply don't compute. "We still have a very hard time imagining forming a planet half the mass of Jupiter out at just .05 AU — close to the hottest portion of the protoplanetary disk," Boss says. (One AU — astronomical unit — is the average distance between Earth and the sun.)

Hot Jupiters would compute if they formed farther out in the disk, where theory predicts, and then migrated inward toward the star. "At first it was a heresy to think that a full-grown massive planet could migrate vast distances within a disk," Ward says. "But the discovery of large extrasolar planets close to stars is circumstantial evidence that giant planets have moved vast distances."



These disks, imaged by the Hubble Space Telescope, contain mostly gas with some dust mixed in. They surround four newly forming stars in the Orion Nebula. The disks are two to eight times the diameter of the solar system and have enough material to form planetary systems like our own. The planet formation process has probably just gotten started within these disks.

Mark McCaughrean (Max-Planck-Institut), C. Robert O'Dell (Rice University), and NASA

If they have, it may have been the result of a cosmic tug of war. The migration hypothesis, first conceived in 1980 by Peter Goldreich of Caltech and Scott Tremaine of the University of Toronto, holds that a giant planet's gravitational field tugs strongly on the disk. But the disk doesn't just sit there, it tugs back. The interplay of forces exerts gravitational drag on the planet, robbing it of orbital angular momentum and forcing it to spiral in toward the star.

The gravitational tug of war may also have a different effect, Lissauer notes, but with the same outcome. A massive planet's gravitational field may be so strong that it torques open a groove in the disk, partitioning the disk into inner and outer regions. According to this hypothesis, the inner region and the planet lose angular momentum to the outer region, causing the planet to spiral inward.

What applies the brakes to keep the planet from cruising into the star and to its death? Two mechanisms have been proposed by Doug Lin of the University of California at Santa Cruz. One invokes tidal interactions between the star and planet and another, powerful stellar magnetic fields. Both have their problems, Lissauer says. So scientists still have some work to do on planet migration.

And why didn't our own Jupiter spiral into the sun? According to Boss, the best explanation is that our protoplanetary disk was short-lived compared to the disks in which the hot Jupiters formed. According to this line of reasoning, right after Jupiter formed, the gas and dust in the disk were all gone. With no disk remaining, there would have been no weird gravitational interplay to force Jupiter to migrate inward. Observational evidence supports this view, Boss says, showing that protoplanetary disks exist for greatly varying amounts of time.

We were lucky that our disk dissipated just after Jupiter formed. Otherwise, Jupiter would have acted like the death star in *Star Wars*: It would have spelled doom for planets in its way — including Earth. Since the hot Jupiters likely did migrate, they probably killed off quite a few terrestrial planets, including some that might have given life a toehold.

"The discovery of hot Jupiters means that there will be some fraction of planetary systems that are inhospitable to life," Boss points out. "In the process of migrating inward, a future hot Jupiter will kick any Earth-like planets it encounters out of its way, ejecting the Earths altogether to freeze in interstellar space or vaporizing them through a collision with the system's star." (A prospect that would no doubt make Darth Vader envious.)

But the mere existence of hot Jupiters does not necessarily mean that Earth-like planets are rare. Based on the number of stars surveyed, it appears that only about five percent of solar-type stars have hot Jupiters. They were discovered first simply because they were the easiest planets to detect. Moreover, now that we know our solar system is not the only one in the universe, it can be argued more persuasively that many stars have planetary progeny. And perhaps some of those planets are hospitable to life.

Boss believes the discovery of extrasolar planets lends more credence to the idea of life outside our solar system than the discovery in 1996 of possible microbial fossils in the martian meteorite ALH84001. "The very fact that we are finally beginning to find extrasolar planets gives the whole concept of extrasolar *life* a tremendous boost," he says. "Even more so than the ALH84001 discovery, which, even if correct, might only be reflecting life that was transported from Earth to Mars, or vice versa, by impacts."

In other words, it's very possible now that there is some larger community out there to which we belong. ■

Tom Yulsman is a former editor of Earth. *He is now a contributing editor to* Astronomy *and an associate professor of journalism at the University of Colorado in Boulder.*

THE SKY SHOW

February's crisp winter skies yield excellent opportunities to view the bright stars of the season. So bundle up and take some time to enjoy these sights as well as the solar eclipse and planetary conjunctions that occur this month. By Martin Ratcliffe and Alister Ling

▶ February opens with an almost first quarter moon skirting less than two moon-widths south of 0.7-magnitude **Saturn**. Aside from the moon, Saturn is the brightest object in its region of the sky, making the planet hard to miss as it lingers high in the southwest at dusk. This is the last full month until autumn to observe the planet in both a dark sky and at a suitable altitude above the horizon. Saturn sets by 11 p.m. local time in early February, along with the faint stars of Pisces the Fish, the constellation currently harboring the ringed planet. A crescent moon, fresh from its eclipse of the sun on February 26, rejoins Saturn on February 28, lying almost 7° southwest of the planet.

Ahead of Saturn, well within the twilight glow of the sun, **Jupiter** and **Mars** hover above the west-southwestern horizon shortly after sunset. Jupiter, at magnitude –2.0, has no trouble shining through the bright horizon glow but sets 80 minutes after the sun on February 1. It sets a few minutes sooner each night after that, then quickly becomes lost to our view by the second week of the month. The planet reaches conjunction with the sun on February 23.

Mars, on the other hand, refuses to hide so quickly, but its lesser brilliance at magnitude 1.2 makes it a more challenging naked-eye target. On February 1 it sets a mere 30 minutes after Jupiter. Try hunting for Mars early in the month using a pair of binoculars. You'll find it 6° northeast of Jupiter. Mars's low altitude will cause it to flicker as our own cooling and turbulent atmosphere disrupts the reddish glow of reflected sunlight from across the solar system.

Four days after the moon glides past Saturn, it enters Taurus the Bull. On February 5, the moon lies east of Aldebaran, the bull's red eye. Earlier, during daylight hours in the United States,

The delicate hues and gentle shading cast by the sun in partial eclipse provide us with a rare softened view of the world. This month's event also gives observers in the southeastern United States an easy opportunity to see Venus during daylight hours.

John R. Foster

FEBRUARY 1998

1 The moon passes 0.6° south of Saturn, 4 p.m. EST

2 Mercury passes 2° south of Neptune, 6 a.m. EST

3 First quarter moon is at 5:53 p.m. EST

5 The moon passes 0.2° north of Aldebaran, 1 p.m. EST
Venus is stationary, 1 p.m. EST

7 Mercury passes 1.4° south of Uranus, midnight EST

11 Full moon is at 5:23 a.m. EST

14 Asteroid Pallas is in conjunction with the sun, 7 a.m. EST

15 The moon is at apogee (251,964 miles from Earth), 9:45 a.m. EST

19 Last quarter moon is at 10:27 a.m. EST
Venus is at greatest brilliancy (magnitude –4.6), 9 p.m. EST

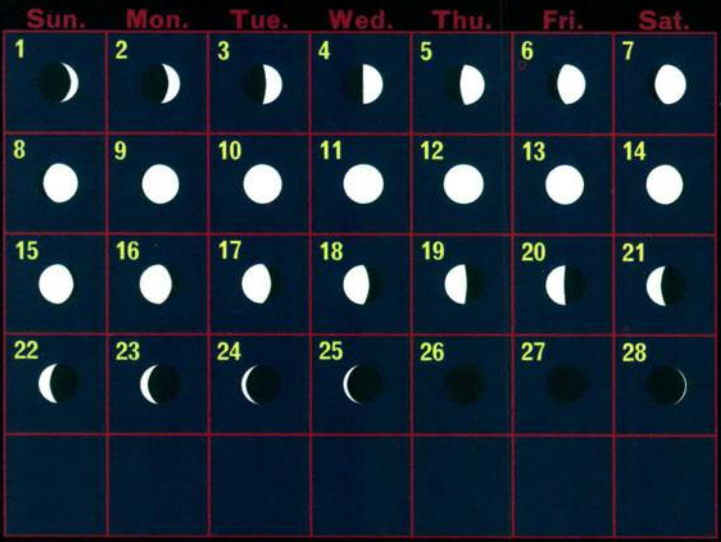
22 Mercury is in superior conjunction, 3 a.m. EST

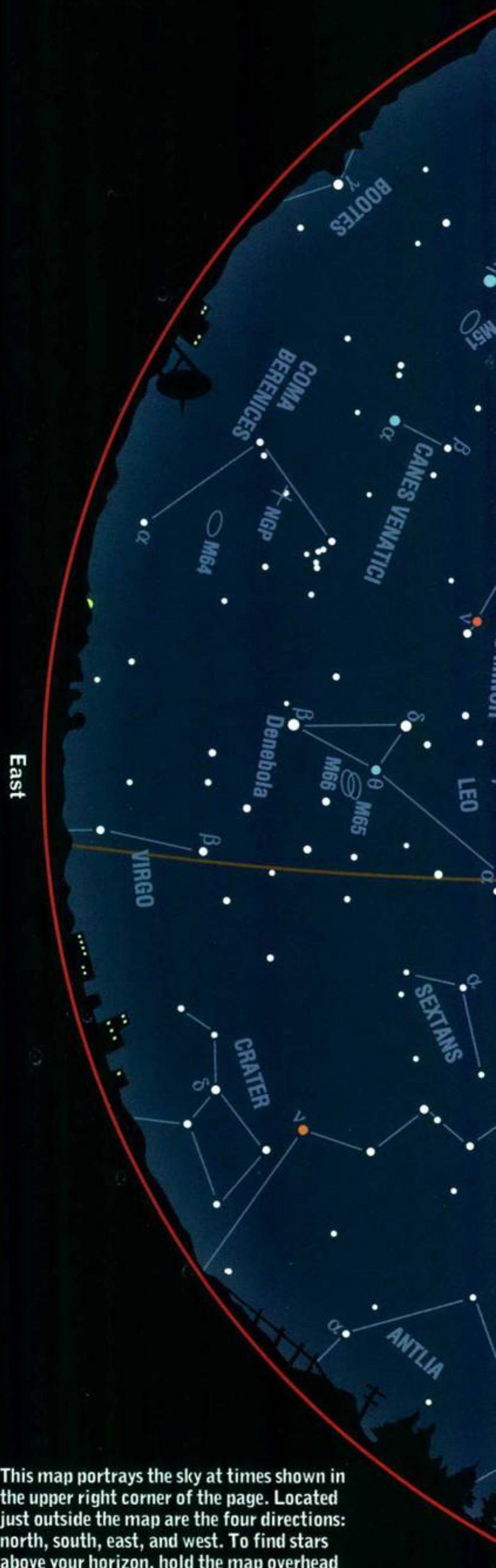
23 Jupiter is in conjunction with the sun, 4 a.m. EST
The moon passes 1.6° south of Venus, noon EST (page 71)

24 The moon passes 3° north of Neptune, 1 a.m. EST
The moon passes 3° north of Uranus, 5 p.m. EST

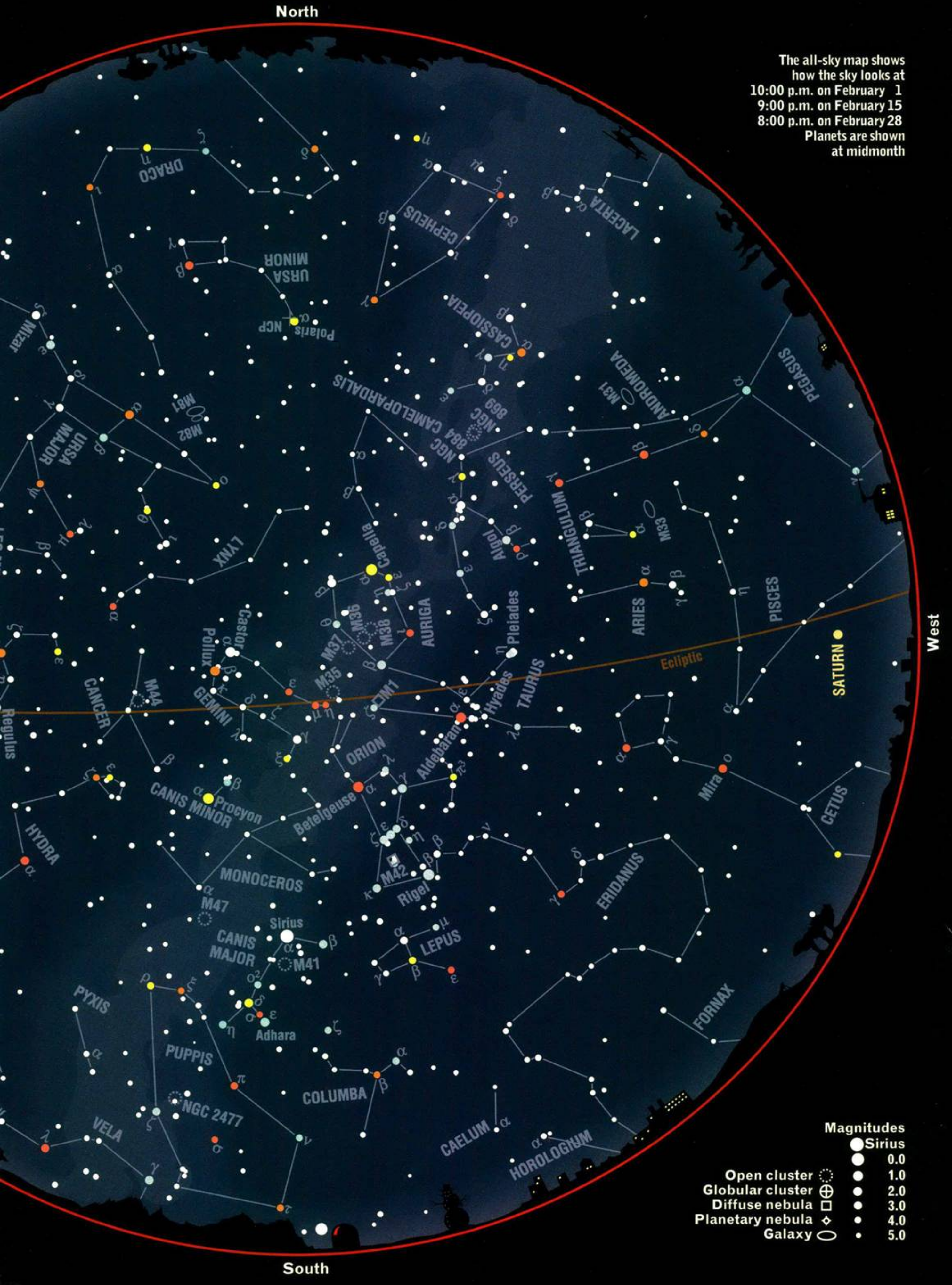
26 New moon is at 12:26 p.m. EST; total solar eclipse

27 The moon is at perigee (223,126 miles from Earth), 2:54 p.m. EST
The moon passes 0.7° south of Mars, 5 p.m. EST
Comet Temple-Tuttle is at perihelion (90.8 million miles from the sun), 9 p.m. EST (page 67)



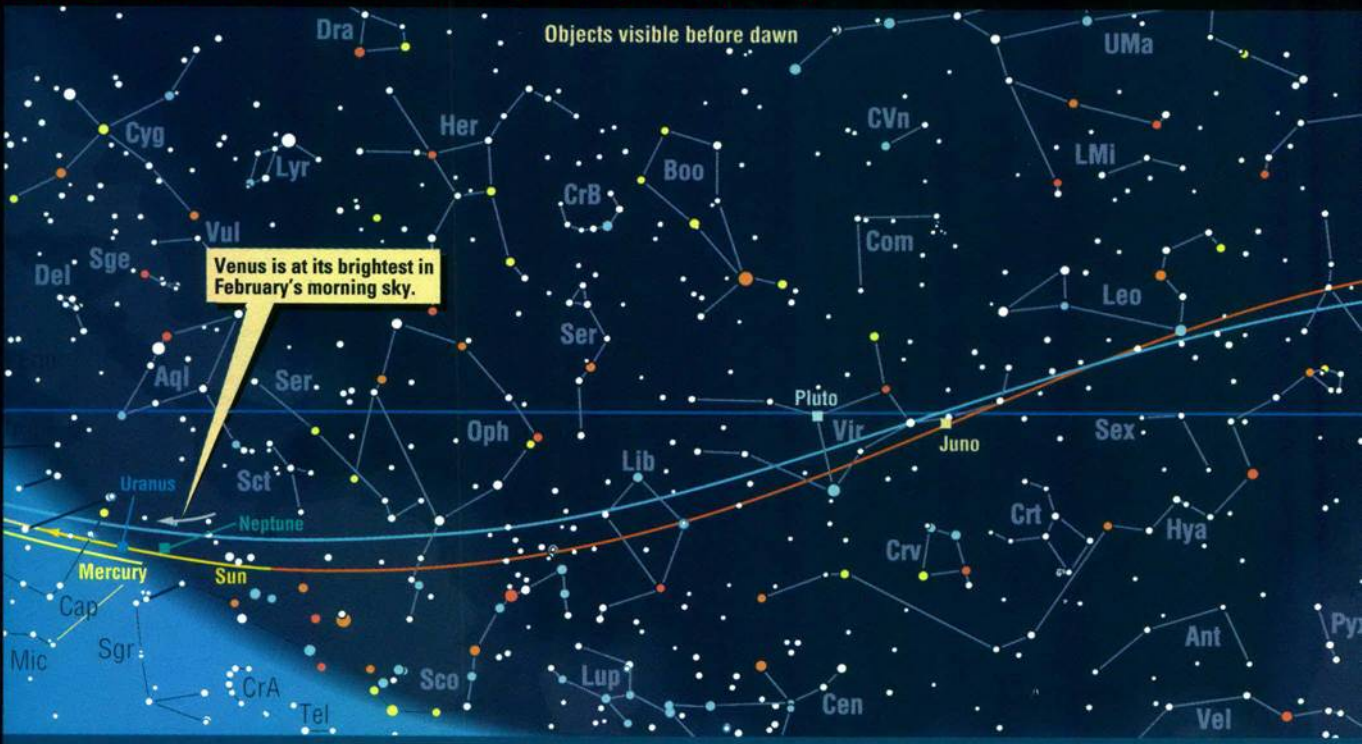


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

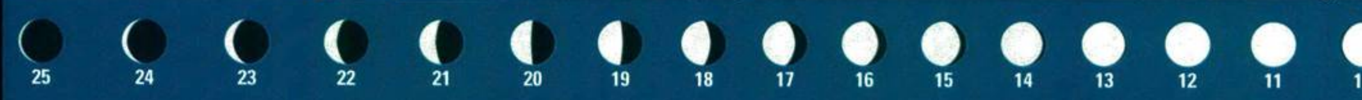

The all-sky map shows
how the sky looks at
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28
Planets are shown
at midmonth

North
South
West
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris
NCP
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
Mizar
M81
M82
URSA MAJOR
CAMELOPARDALIS
NGC 869
NGC 884
PERSEUS
TRIANGULUM
M33
LYNX
Capella
Algol
Pleiades
ARIES
PISCES
AURIGA
M36
M37
M38
Castor
Pollux
M35
M1
Hyades
TAURUS
Ecliptic
SATURN
CANCER
M44
GEMINI
Regulus
Aldebaran
ORION
Betelgeuse
CANIS MINOR
Procyon
Mira
CETUS
HYDRA
MONOCEROS
M42
Rigel
ERIDANUS
M47
Sirius
CANIS MAJOR
M41
LEPUS
PYXIS
Adhara
FORNAX
PUPPIS
COLUMBA
NGC 2477
VELA
CAELUM
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Objects visible before dawn
Dra
UMa
Cyg
Lyr
Her
CVn
LMi
Boo
CrB
Vul
Com
Del
Sge
Leo
Ser
Aql
Ser
Pluto
Vir
Juno
Sex
Oph
Lib
Sct
Uranus
Neptune
Crt
Hya
Crv
Mercury
Sun
Cap
Sgr
Mic
CrA
Tel
Sco
Lup
Cen
Ant
Vel
Pyx

Venus is at its brightest in February's morning sky.


25
24
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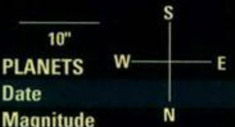
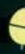
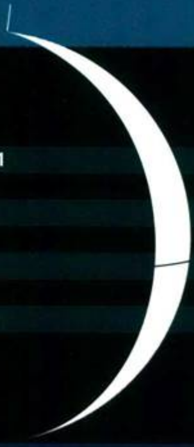
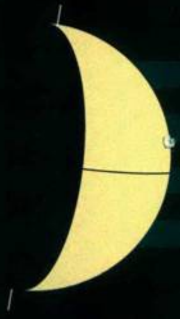
11
1

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.





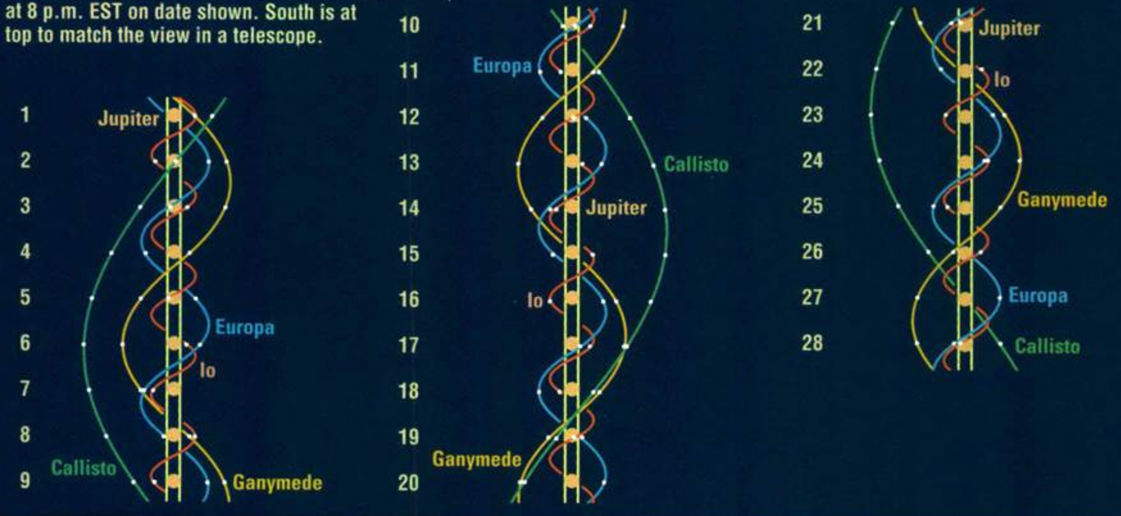


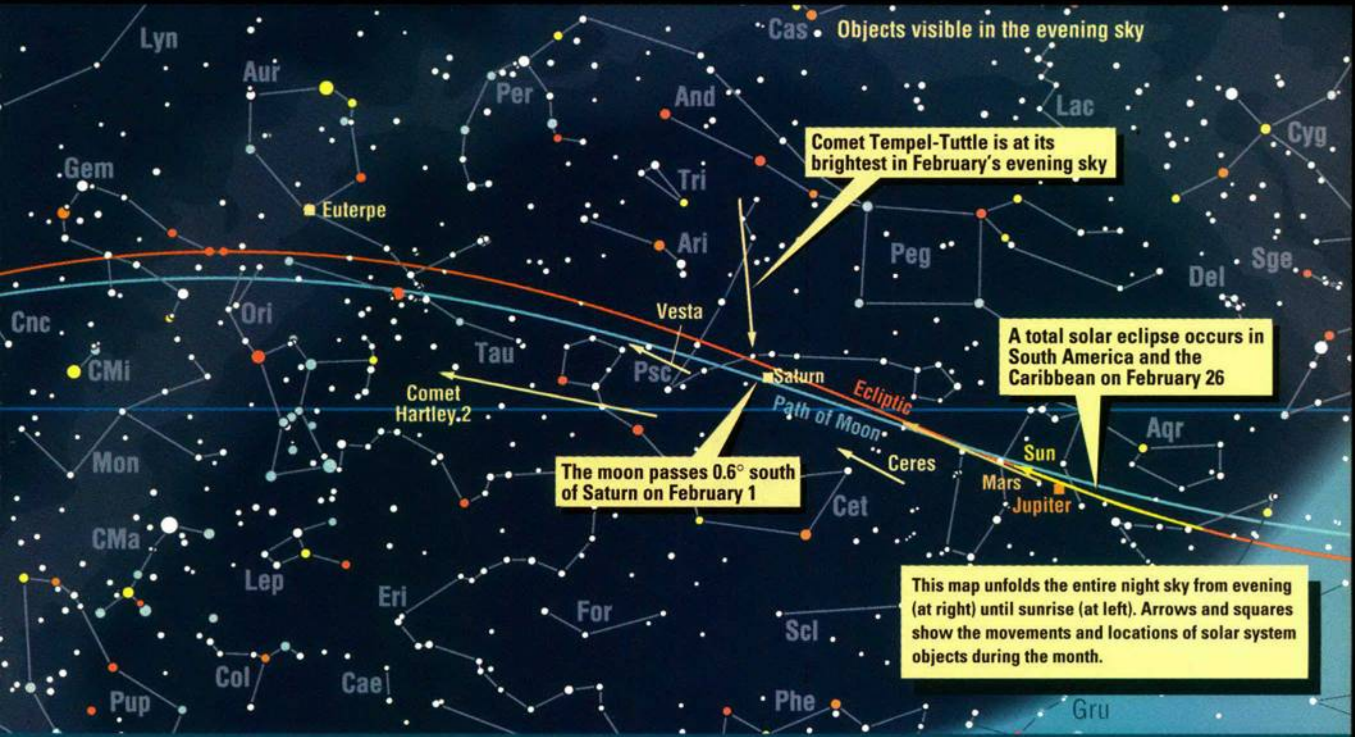


PLANETS	MERCURY	VENUS	VENUS	MARS
Date	February 1	February 1	February 28	February 15
Magnitude	–0.4	–4.5	–4.6	1.2
Angular Size	5.0"	54.9"	35.6"	4.1"
Illumination	92%	9%	32%	98%
Distance (AU) from Earth	1.348	0.304	0.468	2.277
Distance (AU) from Sun	0.465	0.719	0.720	1.392
Right Ascension (2000.0)	19h59.5m	19h18.0m	19h51.1m	23h10.7m
Declination (2000.0)	–22°06'	–14°53'	–15°56'	–6°13'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 8 p.m. EST on date shown. South is at top to match the view in a telescope.




Cas
Lyn
Aur
Per
And
Lac
Cyg
Gem
Euterpe
Tri
Ari
Peg
Sge
Del
Cnc
Ori
CMi
Tau
Vesta
Psc
Saturn
Ecliptic
Path of Moon
Comet Hartley 2
Mon
Ceres
Sun
Aqr
Mars
Jupiter
Cet
CMa
Lep
Eri
For
Scl
Col
Cae
Pup
Phe
Gru

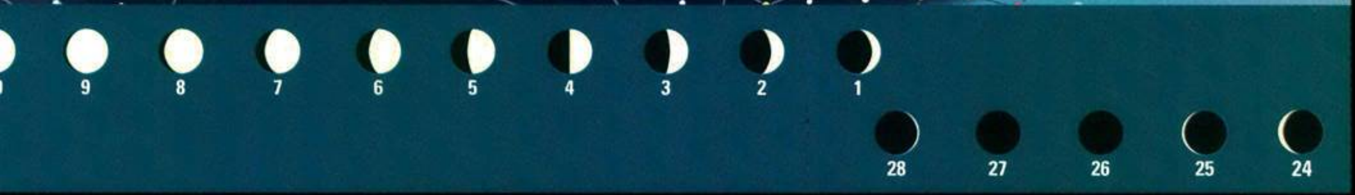
Objects visible in the evening sky

Comet Tempel-Tuttle is at its brightest in February's evening sky

A total solar eclipse occurs in South America and the Caribbean on February 26

The moon passes 0.6° south of Saturn on February 1

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


9
8
7
6
5
4
3
2
1
28
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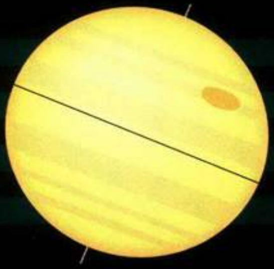
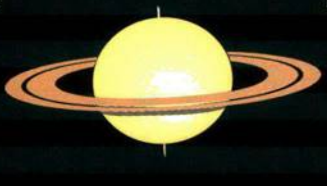
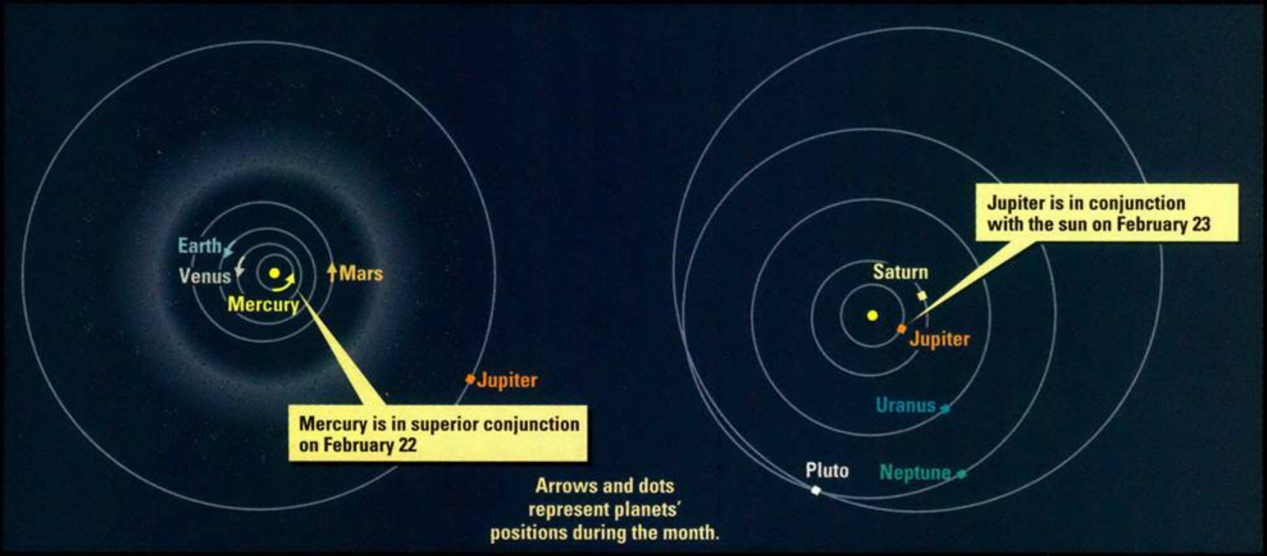
26
25
24





JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 1	February 15	February 15	February 15	February 15
−2.0	0.7	5.9	8.0	13.8
33.2"	16.7"	3.4"	2.2"	0.1"
100%	100%	100%	100%	100%
5.945	9.950	20.795	31.032	30.222
5.013	9.354	19.849	30.144	30.040
22h06.6m	1h05.1m	20h49.4m	20h11.1m	16h32.4m
−12°34'	4°24'	−18°24'	−19°40'	−9°42'

THE PLANETS IN THEIR ORBITS


Earth
Venus
Mars
Mercury
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Mercury is in superior conjunction on February 22

Jupiter is in conjunction with the sun on February 23

Arrows and dots represent planets' positions during the month.

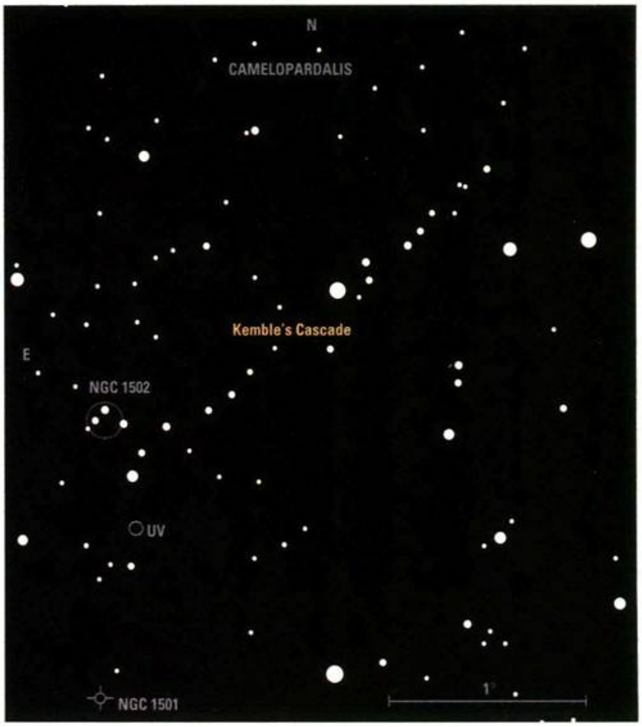
FIRST VIEWS: Kemble's Cascade

Some of my favorite objects in the sky are reserved for binoculars. They sprawl across so much of the sky that a telescope sees right through them. Then there's the sheer comfort of using two eyes to gaze upon a starry field — you just can't beat that.

Kemble's Cascade is a delightful line of 7th- to 9th-magnitude stars some 3° long, strung across the relatively sparse and unfamiliar constellation Camelopardalis. A few of the stars are arranged in pairs, which enhances the beauty of this asterism.

About 20 years ago, Canadian amateur astronomer Lucian Kemble was looking for the open star cluster NGC 1502. Since he appreciated the scenic route of star hopping, he began with binoculars. Immediately he noticed the star chain — the background stars of the outer Milky Way are considerably fainter. Because the brain is particularly adept at pattern recognition, items like a nearly straight chain of stars stand out. Because some members of the group are not perfectly aligned, it was more appropriate to call it a cascade and not a chain.

Lee C.Coombs



The easiest way to locate Kemble's Cascade is to aim at a point half way between Polaris and Capella. Then shift about one binocular field, nearly 6°, toward Alpha Persei. The Cascade may not be very noticeable from a moderately light-polluted area.

As a bonus, the star cluster NGC 1502 (at 4h7.7m 62°20' [2000.0]) can be spotted as a clump near one end of the chain. A pair of yellow luminaries set against a triangular splash of stars makes NGC 1502 worth a look through a telescope.

the moon occults Aldebaran as seen from southern Europe and India. Next month a similar occultation will be observable from the United States mainland.

The most spectacular of all astronomical events occurs on February 26, when a total eclipse of the sun casts the moon's shadow across the Galápagos Islands, northern Colombia, and parts of the Caribbean Sea. Thousands will be flocking to cruise ships and the islands to view the longest solar eclipse to occur until 2001 (See "Plunge into Darkness" on page 74).

During totality, which on this occasion lasts a little over three minutes, observers will get a chance to see several planets. Jupiter (only three days past its conjunction with the sun) and **Venus** can be found to the west of the sun. Venus is currently at its most brilliant, so it should be relatively easy to find. **Mercury** (four days past superior conjunction), Mars, and Saturn all lie east of the sun and should be seen briefly in the middle of the day for those lucky enough to be within the central track of the eclipse. Only within this narrow band, less than one hundred miles wide, will observers see these planets in addition to the stunningly beautiful solar corona.

A total solar eclipse occurs when the moon's disk completely covers the sun's disk. Although the sun is four hundred times larger than the moon, it also lies four hundred times farther away. This coincidence makes the two objects appear to be nearly the same size in our sky. As the eclipse progresses, the moon's dark shadow seems to draw a pencil-thin line across our globe. This dark, central path varies in width along the shadow's course and from eclipse to eclipse. The duration of an eclipse varies due to the slight difference in the moon's apparent size, which is determined by the moon's distance from Earth.

For observers outside the main track, a partial eclipse is visible in certain regions — including parts of the continental United States.

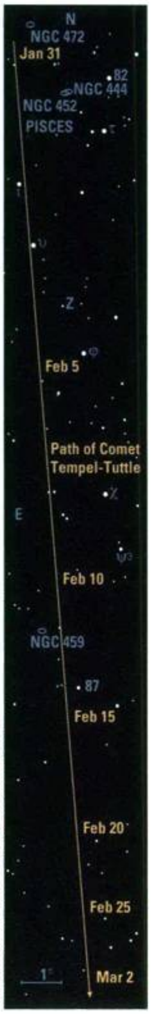
For those who live north of a line from San Diego through central Kansas to north of Chicago, no portion of the eclipse will be visible. The percentage of the moon's shadow seen increases as you move south and east of this line. An eclipse covering less than 20 percent of the sun's disk occurs for states in a band stretching from Texas to Maine. The southern Gulf states and those from Virginia south to northern Florida experience a 20 percent to 40 percent eclipse, while the southern end of Florida sees 50 percent of the sun's diameter in darkness. Correct eye protection is required for viewing all partial phases of a solar eclipse. Suitable filters are sold by many suppliers, or you can use a number 14 arc-welding filter available in welding supply stores.

Venus lies far to the west of the sun this month, and it rises more than 90 minutes earlier. This spectacular "Morning Star" reaches its greatest brilliance at magnitude −4.6 on February 19/20. Just a few days later, on February 23 — days before its rendezvous with the sun — a slim crescent moon passes 1.6° south of Venus. This dramatic pairing takes place east of Sagittarius. Meanwhile Scorpius rises high in the south, and the blue-white jewel named Altair keeps watch from high in the east.

Uranus and **Neptune** lie east of Venus in Capricornus, which is caught in the twilight glow and not visible this month.

Whether you live under the bright glare of city lights or far out in the country, one thing will be evident if you step outside on any clear February evening. Many bright stars shine overhead.

Parent of the Prolific Leonids



All illustrations by *Astronomy*: Elisabeth Rowan

Did you enjoy the display the Leonid meteor shower gave us last November? The Leonids' parent comet Tempel-Tuttle is nearby, but this may be the last month you have a chance to see it. You only have two windows of opportunity in your lifetime to see this periodic interloper in its 33-year orbit.

Tempel-Tuttle spends February falling toward the sun as it heads for its close approach on the 27th, just inside Earth's orbit. From our observation post, the 10th-magnitude fuzzball will glow in the evening sky some 20° above Saturn. By month's end, it closes to within 5° of the planet. Next month it sinks closer to the horizon's glow, where it disappears in the twilight.

At 10th-magnitude the comet will need a dark sky to give you a decent view. If it were three months earlier in its orbit, Tempel-Tuttle would have been significantly brighter and would have generated an incredible meteor storm.

Further information on Tempel-Tuttle and other comets can be found at http://encke.jpl.nasa.gov.

Charles F. Capen

Saturn Shows Off

With the exception of the moon, Saturn is the most awe-inspiring sight for newcomers to astronomy. The steady yellow beacon is well placed this month as an evening object. With its rings open much of the way, Saturn reflects more light than last year, helping it reach 0.7-magnitude.

There is a lot to look for with Saturn in the eyepiece. Once you've had that first glance, stay to observe how much of the planet's shadow falls onto the rings. It really accentuates the 3-D effect. Your next temptation might be to look for the shadow of the rings on the cloudtops, but the rings themselves are in the way. Still, it's pretty hard to miss the darker band that cuts across Saturn where the rings cross in front. That's the thin crepe ring blocking out the light from the clouds behind it.

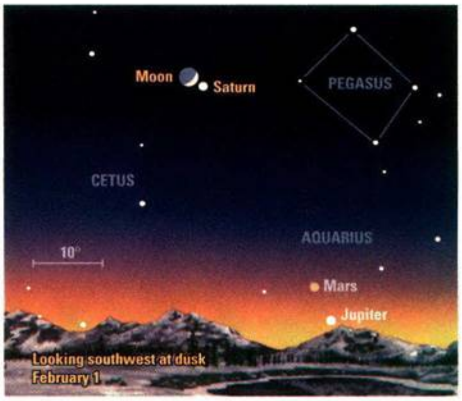
Gregory Terrance

Keep looking at the cloudtops. Slowly scan down the planet, from the pole to the equator and back up again. You'll begin to realize that the bands are different shades at different latitudes. These cloud bands each denote different wind belts, and darker clouds tend to be deeper in the planet's atmophere than the white ones.

If the air is nice and steady, crank up the power and look for the dark division in the rings called the Cassini division. With a 4-inch scope you should be able to detect it on the ends where the rings are open the most. Don't forget the moons! Titan is always visible, and up to seven more moons are waiting for you in larger scopes.

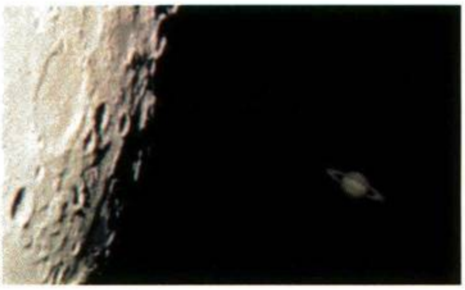
Evening Huddle

Don't miss the lovely sight of Saturn only two moon widths away from a broad crescent on Sunday evening the 1st. If you're lucky, skies past your western horizon will be cloudy. Those clouds will reflect sunlight up to the moon, giving a slight radiance to the shadowed portion — that pale ashen light we call "earthshine."



Looking southwest at dusk February 1

Your binoculars will come in handy for a second pair of objects, Jupiter and Mars. The pair lie roughly a binocular field apart and are crouching closer to the horizon than Saturn. This week will be the last you see of Jupiter for a little while, as it drops down and disappears behind the sun for a couple of months. On the other hand, ruddy and pale Mars hangs in the same spot over the horizon all month. Thanks to its orbital speed, Mars can almost keep up with Earth, so it doesn't seem to move much relative to the horizon. The planet shines at 1.1-magnitude, and begins the month 6° higher up and much fainter than Jupiter.



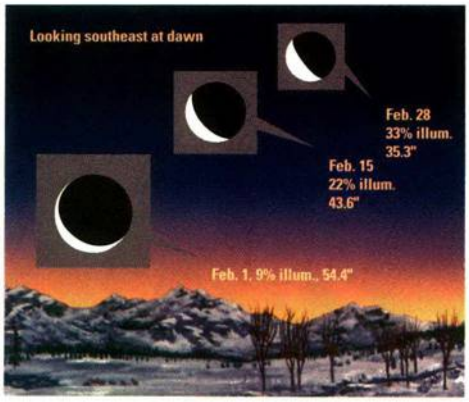
Chris Cook

Metamorphosis of Venus

If you've never seen Venus transform before, this month is your chance. A small spotting scope will readily show the changing phases that dethroned the belief in an Earth-centered solar system.

Eckhard Slawik

Venus has just passed through what is called inferior conjunction — it has overtaken us on the inside orbital track and swings up into the sky quickly. Early in the month, Venus displays a thin 9 percent crescent and spans a large 55" in the eyepiece. By the time March rolls around, it shrinks to 36" across and displays a 32 percent phase.



Venus changes so much in size because it lies between Earth and the sun. As the month progresses, Venus moves quickly away from us. Its dazzling brightness of magnitude –4.4 will remain fairly constant. This is the result of a trade-off between Venus's phase and its distance. Initially, the planet is close to Earth with a thin phase. As it moves farther away, it develops a wider more reflective phase that compensates for the distance.

Don't forget to compare the crescent phase of Venus with the moon's during their meeting on the 23rd. The two should be similar.

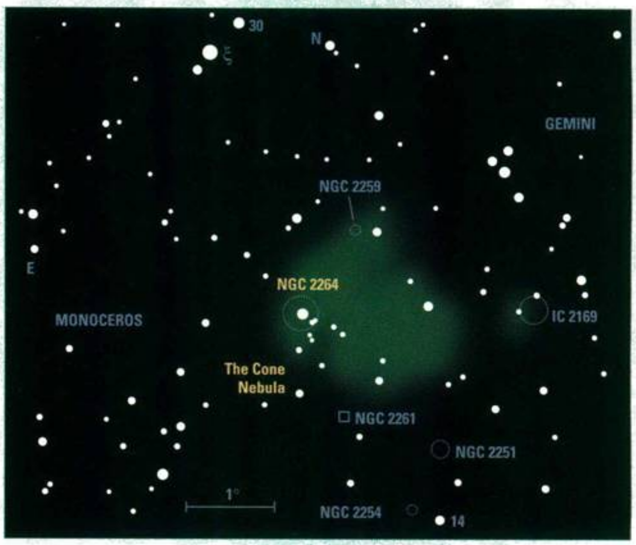
Of these bright nighttime gems, the brightest and most noticeable is Sirius the Dog Star. Sirius has a magnitude of –1.46, making it the brightest star in the heavens. Shortly after the sun sets in the southwest, Sirius is already obvious in the southeast, probably twinkling rapidly. This twinkling, caused by our turbulent atmosphere, turns the normally white-colored Sirius into a kaleidoscope of rapidly changing color. This effect often startles first-time viewers, and planetariums across the country receive calls about "a hovering white object with colors rotating around it."

Sirius is bright due to its closeness to us. Only 8.7 light-years away, it is among the ten closest stars to the sun. Sirius is twice as massive and twice the diameter of the sun and pours out 20 times more light. It lies in the constellation Canis Major the Great Dog.

Above and to the right of Sirius lie stars far more powerful, but they are at a greater distance and therefore appear less bright in our skies. The striking group known as Orion the Hunter includes ruddy Betelgeuse and blue-white Rigel. These two stars, both supergiants, lie above and below a line of three bright stars that are rather close together. These stars represent the belt of Orion; Betelgeuse is the hunter's right shoulder and Rigel his left foot. Notice how the three belt stars point toward Sirius. Now move in the opposite direction from Sirius to find Aldebaran, the red eye of Taurus the Bull.

High above the southeastern horizon during the early evening hangs Gemini the Twins — a bright

OBSERVER'S CHALLENGE: The S Monocerotis Nebula



All astronomers are familiar with the images depicting a dark triangular gap (the Cone Nebula) cutting into a bright red emission nebula (NGC 2264). However, few know that the red, faint, and visually difficult emission nebula is also home to a brighter reflection nebula surrounding S Monocerotis. This nebula is usually overexposed and buried behind the red wisps on photos — so observers are frequently unaware that it exists.

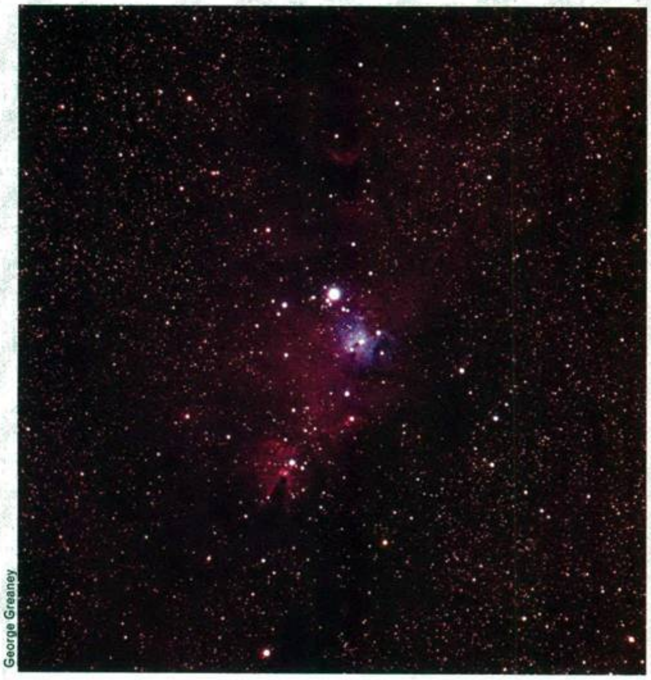
Short exposures reveal a familiar object to winter deep-sky observers — the Christmas Tree Cluster, NGC 2264. These pictures are typically too short to reveal the white reflection nebula, though a nice image may be found in *Burnham's Celestial Handbook*.

Start at low power and take the time to enjoy the cluster, which is 25' tall — just short of the moon's size. As you bump up the magnification, you'll start to see a fair number of double stars. To detect the nebula, you'll need to boost the magnification up to 100-150x on at least a 6-inch scope. Now check out the haze surrounding the brightest star, S Monocerotis. Unless you have very clean optics or are under a really dark sky, you might not be able to tell the difference between the circular light gray reflection nebula and an artificial haze.

Here are a couple of techniques for observing reflection nebulae around bright stars. The simplest is to move the star so it's just outside the field of view. If the haze disappears, then it was caused by light scattered through dirty optics. If the haze remains, you've bagged the nebula. A different technique is to take an infrequently used eyepiece that has a field stop (a circular lip) in the barrel. Tape some tin foil or stiff construction paper onto the inside of the lip so that a nice sharp edge of the material juts into the field of view. Place the star behind the dark block and you'll get a chance to see the nebula.

The great observer William Herschel did not pick up the nebulosity, though his son John did discover it a number of years later. Experienced observers recognize that if William missed an object, it's not going to be an easy target.

NGC 2264 can be found at 6h41.1m 9°53' (2000.0).


George Greaney

constellation residing along the ecliptic, through which a gibbous moon passes on February 7 and 8. By midnight the twins lie practically overhead. On February 8 Castor and Pollux, the two 1st-magnitude stars in Gemini, lie above the moon. Castor (Alpha [α] Geminorum) shines at magnitude 1.6 and is actually fainter than Pollux (Beta [β] Geminorum), which shines at 1.1. Some astronomers believe their respective brilliances have reversed over the last three centuries. Castor itself is a fine binary star, the two stars separated by one magnitude. Small telescopes reveal the star's double nature, and a 4-inch scope will split the components easily. The two stars lie 4" apart and are 47 light-years away. While in the area, note two other double stars in the same low power field of view, one a degree to the west and another a degree south of Castor.

The sky canopy slowly rotates around the pole star during the cold night, causing us to say goodbye to the Great Square of Pegasus setting in the west. The friendly "W"-shaped Queen Cassiopeia gently sinks from its high point to the northwest, while far below it the bright star Deneb hovers near the northern horizon.

The bright winter stars swing through the meridian throughout the night, proudly boasting their dominance of the night sky. However, silently and persistently, the king of the beasts, Leo the Lion, rises in the east. The moon, just one day past full, passes 2° south of its brightest star, Regulus, on February 11.

North of Leo, rising in the northeast in preparation for its high ground during the forthcoming spring, is the Big Dipper. This is a fine time to begin discovering the wonderful galaxies that dot this region of space – during the dark winter nights when the moon is out of the way.

Good practice for spotting galaxies can be acquired by hunting down Comet Tempel-Tuttle, the parent comet to the Leonid meteor shower. The month opens with Tempel-Tuttle lying 4.5° southwest of M33, a large face-on spiral galaxy in Triangulum. Then it heads rapidly south, tracking through Pisces, toward its February 27 perihelion. On this date it lies 4° due north of Saturn. The comet should be visible with a pair of large binoculars, but it will not give you the spectacular views we had with comets Hyakutake and Hale-Bopp. Dim Temple-Tuttle will be glowing no brighter than 9th-magnitude. It has been receding from Earth, and hence fading, since January 17, the date of its closest approach to Earth. The comet has a 33-year period and is expected to generate a major meteor shower in November 1998 or 1999. **A**

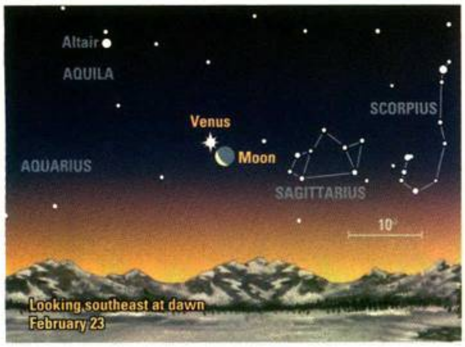
Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

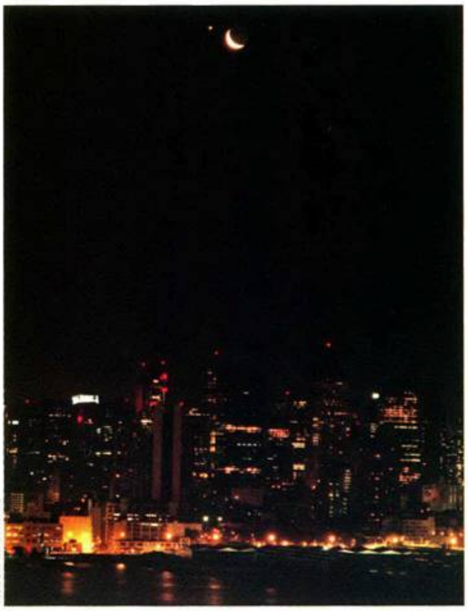
Early Riser's Treat

One of winter's few advantages is a late sunrise. By 7 a.m., many people are already awake. If you're such a person, take the time to look eastward and watch the always lovely Venus-moon conjunction.

On the morning of the 22nd, the moon hangs to the upper right of Venus. By the 23rd, it scoots 3° south of Venus. Use the opportunity to take pictures of the pair against a cityscape. An awaking city has a different feel from the evening scene. More lights are off, giving the city a quieter look. The city outline has changed, as well. Now you're shooting from the west side instead of the east.

One day later the crescent moon's horns point back up to blazing Venus.





Robert B. Slobins

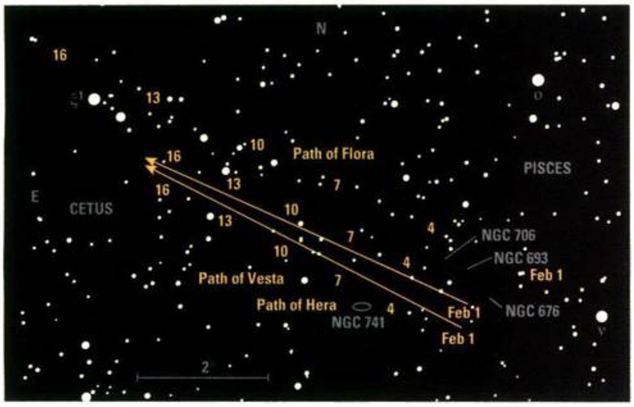
Double Your Value

Asteroids 4 Vesta and 8 Flora team up for a parallel play across the sky. One advantage of looking for asteroids: It can be done from a moderately light-polluted backyard. Their star-like appearance allows them to punch through the gray skies more easily than galaxies.

The duo starts off together in eastern Pisces and then moves eastward. 8 Flora has a greater speed because its orbit lies inside Vesta's. Despite being farther away than Flora, Vesta's larger size (300 miles) makes it shine more brightly at magnitude 8.2, compared to Flora's 65-mile size and 10.3-magnitude brightness.

Observers in darker skies can try to spot some nearby galaxies including 10.5-magnitude NGC 676 and 11.1-magnitude NGC 741. Two fainter galaxies (NGC 693 and NGC 706) shining at magnitude 12.5 will probably be lost to the moonlight at the start of the month.

If you have good skies or are working with a CCD camera, try to catch the fainter asteroid 103 Hera tag-teaming with Vesta. She'll be about 20' north of Vesta for much of the month.



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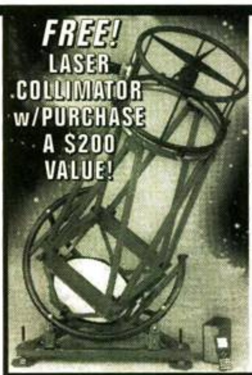

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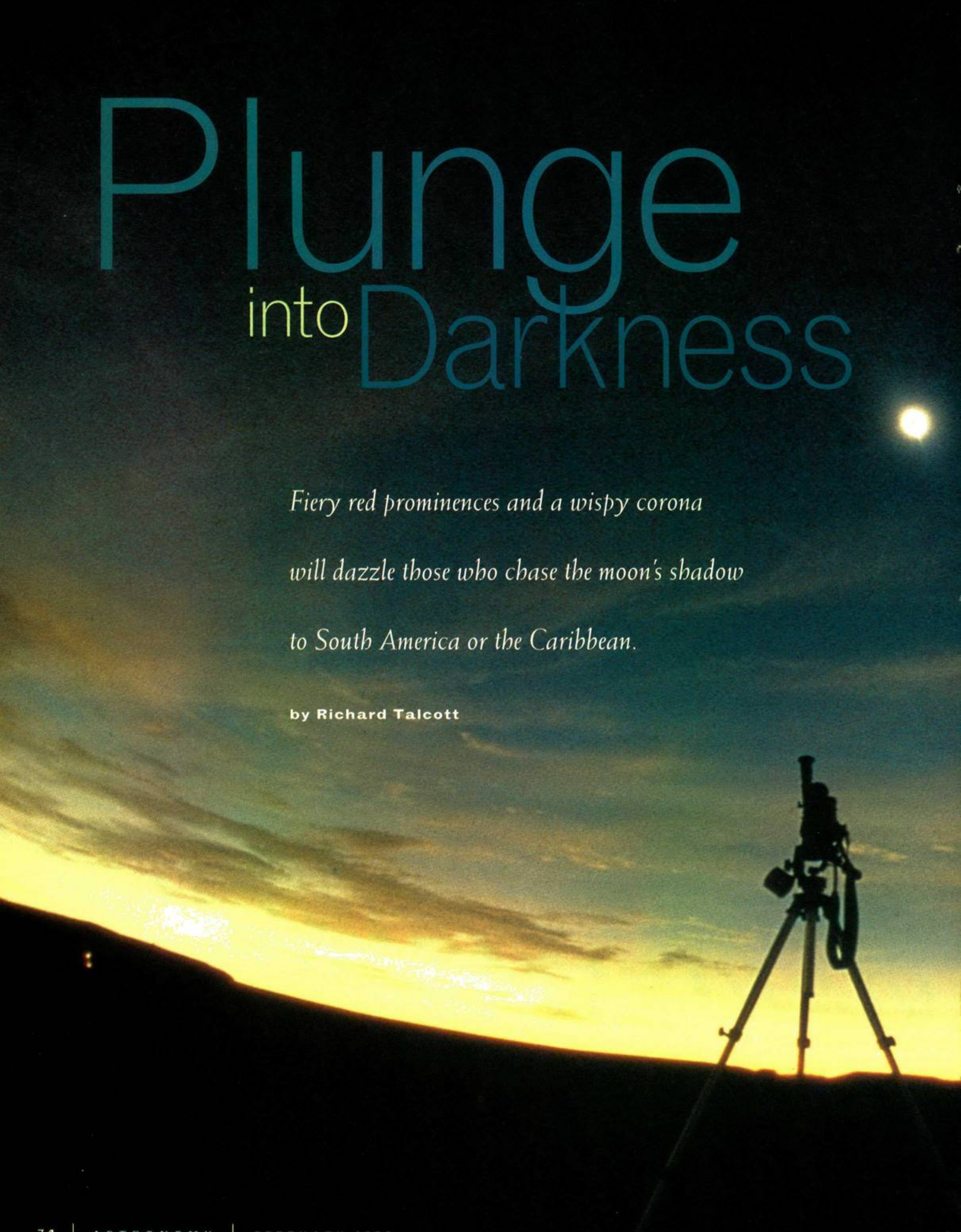
Plunge into Darkness

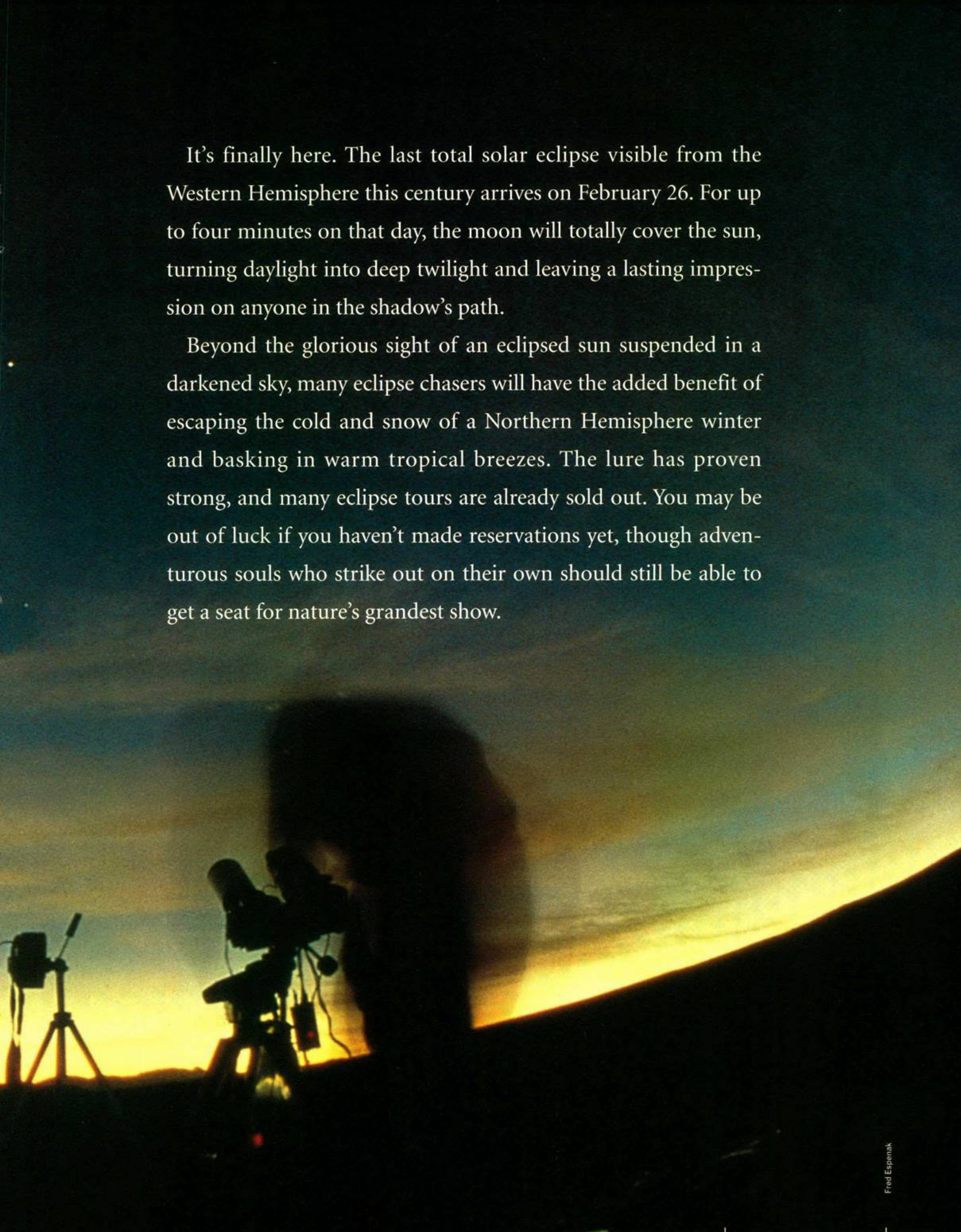
Fiery red prominences and a wispy corona will dazzle those who chase the moon's shadow to South America or the Caribbean.

by Richard Talcott



It's finally here. The last total solar eclipse visible from the Western Hemisphere this century arrives on February 26. For up to four minutes on that day, the moon will totally cover the sun, turning daylight into deep twilight and leaving a lasting impression on anyone in the shadow's path.

Beyond the glorious sight of an eclipsed sun suspended in a darkened sky, many eclipse chasers will have the added benefit of escaping the cold and snow of a Northern Hemisphere winter and basking in warm tropical breezes. The lure has proven strong, and many eclipse tours are already sold out. You may be out of luck if you haven't made reservations yet, though adventurous souls who strike out on their own should still be able to get a seat for nature's grandest show.



Fred Espenak

Spencer R. Rackley IV

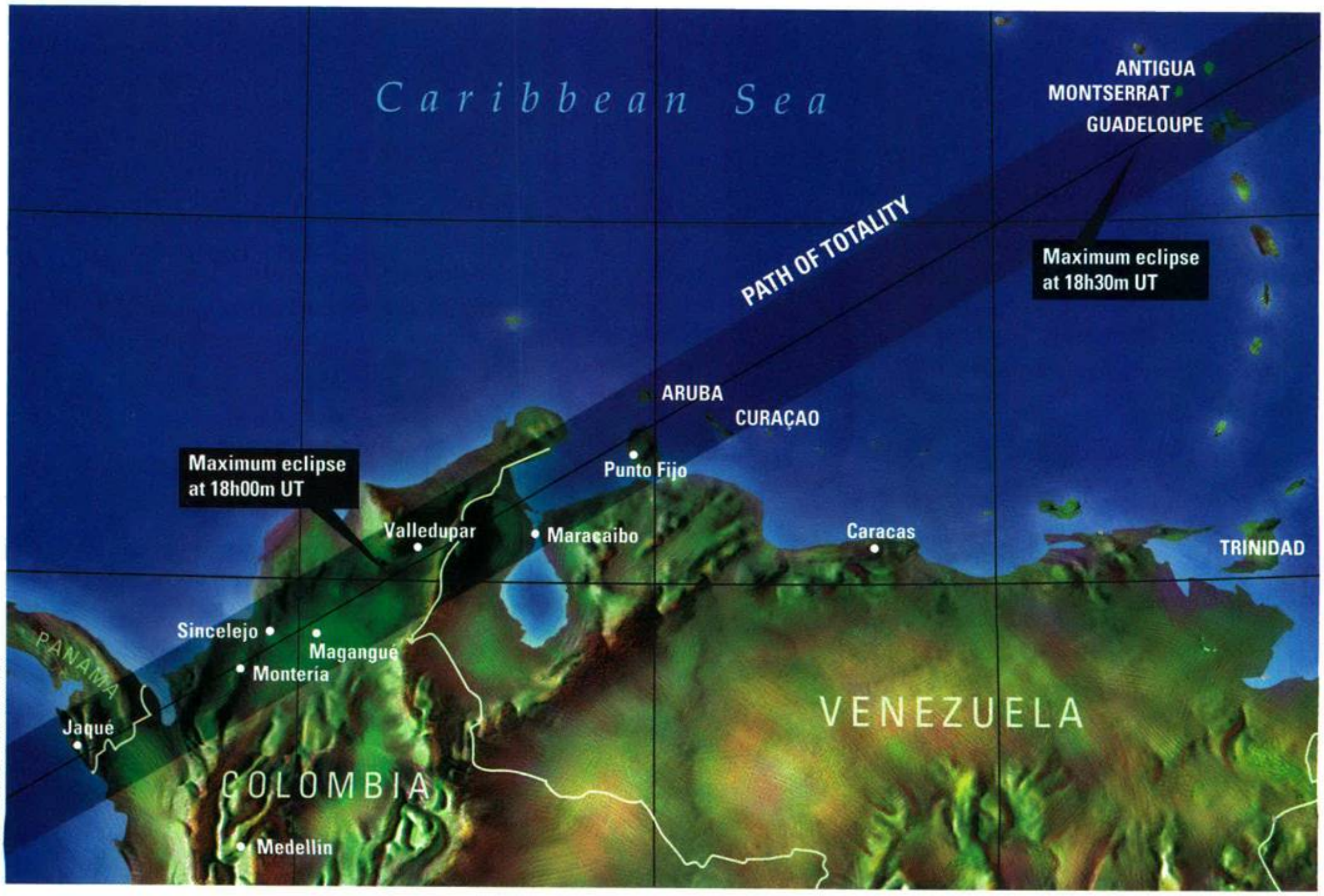
What could be nicer than the Caribbean in February? Chasing the moon's shadow on a cruise ship is one way to view this eclipse, or you can sun yourself on one of the many islands lying in totality's path. Either option offers a warm respite from winter temperatures.

Where to Go

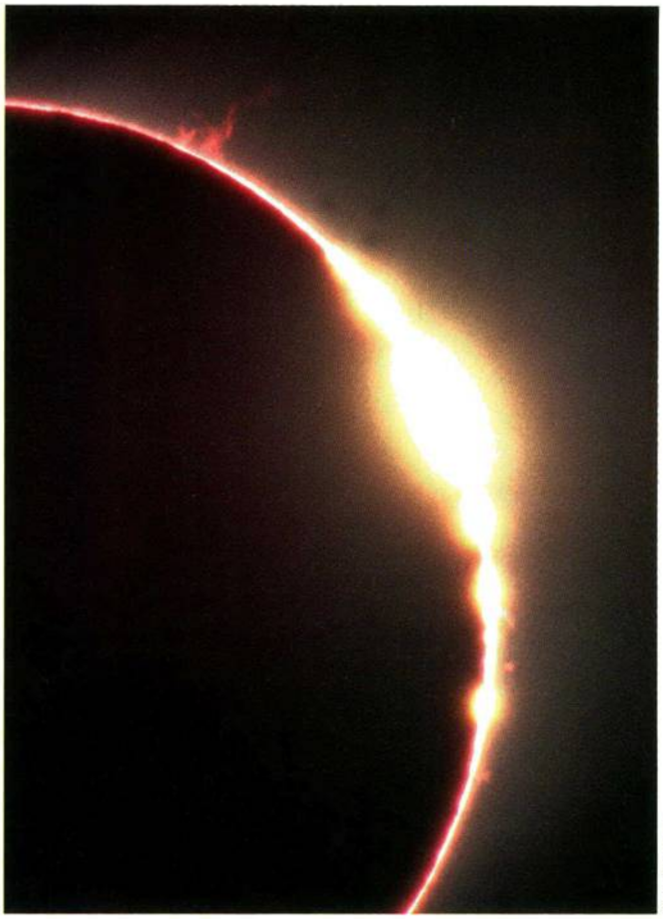
After its first contact with Earth's surface in the mid-Pacific, the moon's shadow races across 3,500 miles of open water in about an hour and 15 minutes before making landfall in the Galápagos Islands, about 750 miles off the coast of Ecuador. The path of totality doesn't make a direct hit on the Galápagos but clips the northern edge of this famed island group. Although the center line remains north of the islands, Isla Pinta, Isla Marchena, and northern Isla Isabela all witness totality. Ecuador's government restricts access to these wildlife sanctuaries, however, so excursions to this exotic locale are now probably out of the question. On the center line north of the islands, totality arrives at 11 a.m. local time and lasts nearly four minutes.

The shadow's path then heads to the northeast, arriving on land again where Central America joins South America. (The moment of greatest eclipse occurs in the Pacific between the Galápagos and the mainland, where the moon hides the sun for 4 minutes 8 seconds.) The path then crosses the southern tip of Panama, northern Colombia, and northwestern Venezuela before moving into the Caribbean Sea. The largest city in the path of totality is Maracaibo, Venezuela, where the sun disappears from the sky for 2 minutes 50 seconds starting at 2:04 p.m. local time.

The eclipse track makes landfall several times in the Caribbean. First to see a midday nightfall are Aruba and Curaçao in the Netherlands Antilles (the northern tip of Bonaire also gets in on the action). After a long stretch over water, the moon's shadow strikes land again in the Leeward Islands. Montserrat, Guadeloupe, and Antigua all witness totality, which lasts up to 3 minutes 16 seconds on

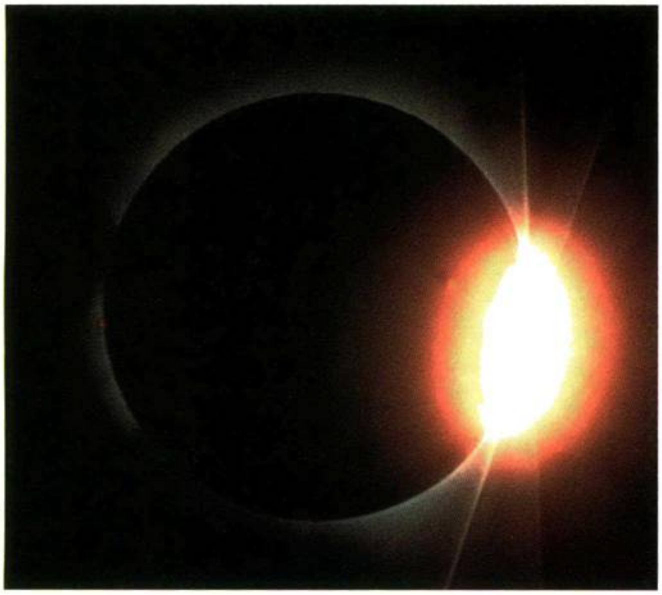

Caribbean Sea
ANTIGUA
MONTSERRAT
GUADELOUPE
PATH OF TOTALITY
Maximum eclipse at 18h30m UT
ARUBA
CURAÇAO
Punto Fijo
Maximum eclipse at 18h00m UT
Valledupar
Maracaibo
Caracas
TRINIDAD
Sincelejo
Magangué
Montería
PANAMA
Jaqué
VENEZUELA
COLOMBIA
Medellín

All Maps/*Astronomy*: Elisabeth Rowan



Like a sparkling string of jewels, Baily's beads glitter along the advancing moon's edge just before the last sunlit dance of the diamond ring (right). Named after the 19th-century amateur astronomer Francis Baily, the beads are shafts of light cutting through valleys along the lunar limb.

W. L. Reyna, Jr.



This glorious solitaire, known as a diamond ring, announces the impending arrival of totality (below). Lasting for just a few seconds, it is the last bit of sunlight streaming through the deepest valley along the moon's limb.

Fred Espenak

the center line around 2:30 p.m. local time. The path then heads across the Atlantic, leaving Earth as the sun sets a little west of the Canary Islands.

The weather prospects for this eclipse appear generally good. The Galápagos have the most variable weather at this time of year, with the cloud cover averaging about 45%. In South America, the prospects improve as you move east. Areas along the Pacific Coast tend to be cloudy, although February is a relatively dry month. You should be better off heading to northeastern Colombia or Venezuela, where cloud cover this time of year averages only about 30% and February is the driest month of the year. Nearby Aruba and Curaçao join in these stellar weather prospects, with little to recommend one area over another. Prospects in the Leeward Islands are not quite as bright, with the average cloud cover climbing back toward 45%. However, much of that cloudiness occurs over higher elevations — sea-level sites should prove a better bet. Barring widespread cloud cover, cruise ships may offer the best chance for clear skies. They offer both the mobility to avoid clouds and the up-to-date weather information to know where the clouds are.

How to View It

Assuming the sky is clear on eclipse day, you'll be in for a grand show. But don't plan to view the sun as easily as you would other celestial objects: Without proper eye protection, observing the sun is fraught with danger. You can seriously damage your retina by viewing even a partially eclipsed sun for as little as 30 seconds, even without any optical aid. (And because the retina lacks pain receptors, the damage occurs without warning.) With the increased light-gathering power of binoculars or a telescope, the retina can burn in just a fraction of a second.

Not an eclipse goes by without dozens of people, many of them children, damaging their eyes. But don't let fear keep you from enjoying the eclipse. With proper protection, the partial phases can be viewed in complete safety. And once totality arrives, you don't need any protection at all. The totally eclipsed sun can be observed with the naked eye, binoculars, or a telescope with impunity. Just be aware of totality's end so you don't accidentally look at the sun when it starts to come back into view.

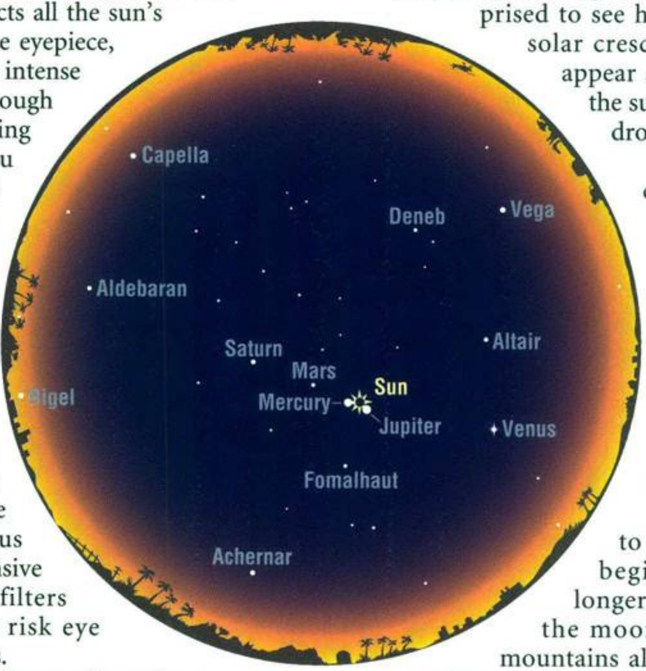
To see the partial phases of an eclipse, you can either view the sun directly through a high-quality solar filter or indirectly by projecting an image of the sun. Three types of filter material work well, whether you plan to look with the naked eye or with optical aid. Inexpensive but perfectly safe is a #14 arc-welder's glass. The glass, which can be found at welding supply stores, comes in rectangular pieces measuring about 2 by 4 inches and imparts a greenish hue to the sun. Unfortunately, the glass's optical quality isn't high enough to use with a telescope or as a photographic filter. It functions best for naked-eye viewing.

The second option is to use a Mylar filter, which consists of one or two sheets of Mylar plastic coated with a thin layer of aluminum. These filters, excellent both for naked-eye and telescopic observing, render the sun a blue-white color. Never use Mylar sold as "space blankets," window insulation, or candy wrappers as a solar filter. They are too flimsy and transmit far too much light.

Option number three is a metal-on-glass filter, which features a nickel-chromium alloy deposited onto optical-quality glass. Designed to fit over the front of a telescope, these filters yield an aesthetically pleasing yellow-orange sun. Suppliers of both Mylar and metal-on-glass filters advertise in *Astronomy.*

Avoid using any other type of filter. The most dangerous type is the so-called sun filter that comes packaged with many department-store telescopes. These filters screw onto a telescope's eyepiece and absorb the light there instead of intercepting it before it enters the telescope. The telescope's lens or mirror still collects all the sun's radiation and focuses it near the eyepiece, however. The filter absorbs this intense heat and may break, letting through the sun's full intensity and risking near-instant blindness. If you own one of these filters, do yourself a favor and throw it away immediately.

Other filter materials that can prove dangerous include either black-and-white or color film, sunglasses, smoked glass, polarizing filters, or neutral-density filters. Although these devices do a good job of blocking visible light, they transmit large amounts of the sun's hazardous infrared radiation. With inexpensive arc-welder's glass and Mylar filters available, there's no need to risk eye injury by using these other filters.



You can also view the partial phases of an eclipse indirectly by projecting an image of the sun. One easy way is to cut a square hole in a piece of cardboard and tape some aluminum foil over it. Then with a straight pin, poke a small hole in the foil. To observe the eclipse, let the sun's light pass through the pinhole onto a second piece of white cardboard, which serves as the screen. Remember, don't look at the sun directly through the pinhole, instead view the image of the sun projected on the screen.

What You Will See

On February 26, all the eclipse action takes place in a two- to three-hour period. That may seem like plenty of time to see and do everything you want, but you'll quickly find that's not so. Time has a strange way of seeming compressed during a solar eclipse.

The eclipse begins at first contact, when the moon's limb first appears to touch the sun. If you're observing with a group, you can count on a contest to see who first spots the telltale nick in the sun's disk. The next hour or so is one of excited anticipation. You'll find yourself glancing at the sun occasionally to make sure that the moon is making progress. If you didn't know better, you might not be aware that an eclipse is taking place. The signs are subtle and the pace of change slow.

Once the moon has covered more than half of the sun, look at the shadows underneath any nearby tree or bush. Each of the tiny gaps between the leaves acts as a pinhole, projecting an image of the eclipsed sun. Don't be surprised to see hundreds or thousands of little solar crescents. Shadows in general will appear sharper as the apparent size of the sun shrinks, and you may notice a drop in temperature.

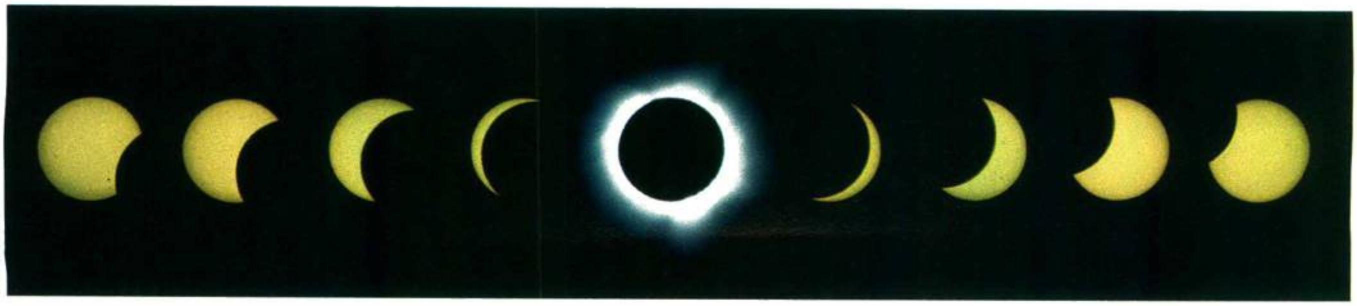
As the sun wanes to a thin crescent, about ten minutes before totality begins, start scanning the sky for bright stars and planets. You should easily spot brilliant Venus, shining at magnitude –4.6, which lies 42° west of the sun and is nearly at its brightest for the year. During totality, you can expect to see objects as faint as 3rd magnitude.

As the solar crescent dwindles to just a tiny sliver, it eventually begins to break up. Sunlight no longer forms a complete arc around the moon's advancing limb. Instead, mountains along the limb poke up through the ever-thinning crescent. As the moon continues its relentless march, more mountains cut off the sun's light, and the only places sunlight passes through are valleys along the lunar limb.

Arrayed along the moon's advancing edge like a string of pearls, these brilliant points of light are known as Baily's beads, named after the 19th-century English astronomer Francis Baily who first described them in detail. As Baily's beads dwindle in number, steal a few seconds from sungazing and look toward the western horizon. About 15 seconds before totality you'll see the moon's shadow descending like a huge wall of darkness. Traveling at supersonic speed, the looming shadow announces the imminent arrival of totality.

With just a few seconds to go now, the jewel-like Baily's beads shrink to a final solitaire, known as a diamond ring.

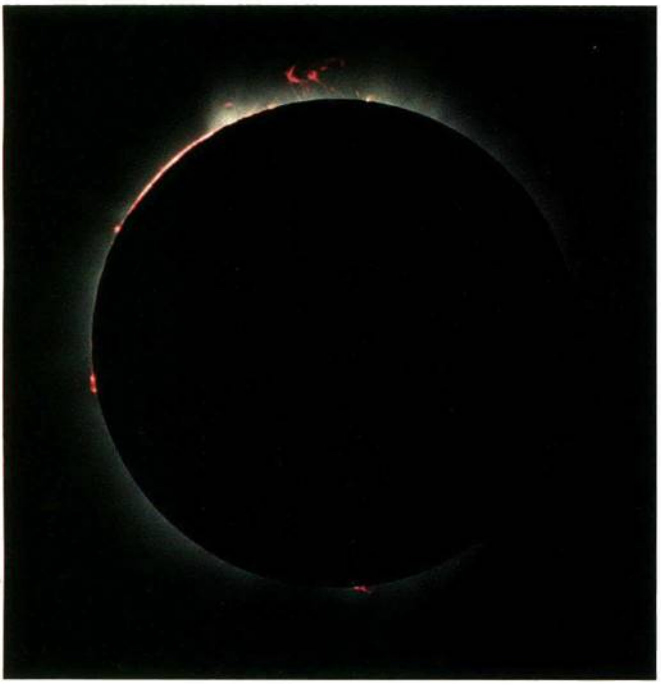
The whole shebang. A composite of nine separate images shows the moon's shadow marching across the face of the sun. When the sun is completely covered, be sure to take a few moments to look at your surroundings. Can you spot five planets and some of the brighter stars that will be visible once the sun's light goes out?



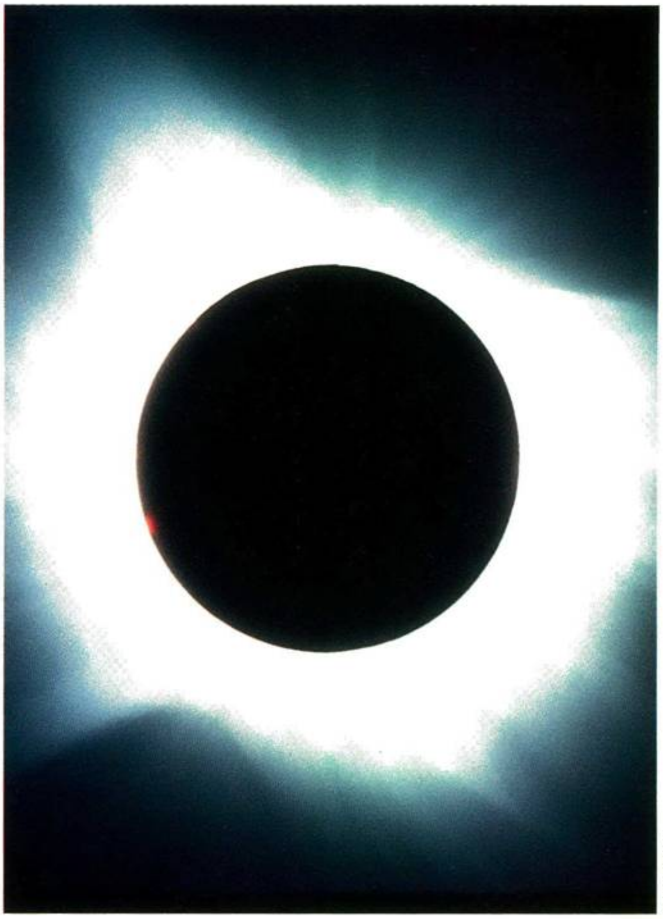
Fred Espenak

In one of Nature's grandest displays, spectacular coronal streamers seem to flow from the sun's darkened face during a total eclipse (right). Look for these as well as the delicate swirls and loops of the corona that are normally drowned out by the sun's brilliant photosphere.

Tendrils of hot gas known as prominences arc above the sun's surface during the total solar eclipse of July 11, 1991 (below).



Roland and Marjorie Christen



Ralph Malaker

This last bit of sunlight streams through the deepest gap on the moon's limb, providing the disappearing sun with a final moment of glory before totality reigns.

Nightfall at Midday

As soon as the diamond ring is extinguished, remove the solar filters from your telescope, binoculars, and camera. The totally eclipsed sun poses no threat to your eyesight because the harmful surface of the sun, the photosphere, is hidden safely behind the moon.

The next feature you'll see pops into view along the moon's advancing limb about five seconds after totality commences. It is the chromosphere, a vivid red layer of the sun's atmosphere just above the brilliant photosphere. Look quickly — the chromosphere is only about 1,000 to 2,000 miles thick, so the moon soon covers it up.

Once the chromosphere slides from view, you're in the glory of totality. The most spectacular sight is the sun's corona, a gauzy, pearly-white light that typically stretches two or three times the diameter of the uneclipsed sun. This outermost region of the sun's atmosphere extends millions of miles above the surface.

It will take a moment for your eyes to grow accustomed to the sudden darkness and appreciate the glorious corona. Look for delicate loops, swirls, and streamers. You may be surprised at how bright the corona appears — it's roughly half as bright as the full moon. You don't normally see it because the photosphere drowns it out.

Also keep an eye out for prominences, the fiery red tongues of gas that arc above the chromosphere into the corona. Larger prominences may stay in view throughout totality, but the smaller ones appear or disappear as the moon advances.

If you observe from a location with at least a couple minutes of totality, it's worth tearing yourself away from the sun briefly to take in the surroundings. Notice the color of the sky and the twilight hues that ring the entire horizon. These colors come from sunlight just outside the area of totality.

The sky itself takes on the appearance of twilight about 30 minutes after sunset. In addition to Venus, Jupiter (just three days after its conjunction with the sun) and Mercury will be easy to spot. Look for them just a few degrees from the sun. Mars and Saturn, significantly fainter than the other three planets, will be harder to glimpse but should be visible if the sky is clear. In addition, several stars of the summer and autumn skies should pop into view.

Totality will seem to end almost as soon as it begins. Third contact, when the first glint of sunlight from the photosphere appears and drowns out the corona, signifies the end of totality and the time to use filters for all future observations.

But the eclipse is far from over. Everything you saw between first and second contact now plays out in reverse. First you'll see the diamond ring (opposite where the pre-totality one appeared), then Baily's beads. Watch too as the moon's shadow speeds off to the east, and think of the lucky souls out there waiting for their view of totality. ■

Watch for eclipse reports at Astronomy's *website: http://www.astronomy.com. Richard Talcott will be observing totality from Celebrity Cruise Line's* Galaxy *near Antigua. Along with his fellow editors, he will be reporting on the eclipse in the June 1998 issue.*

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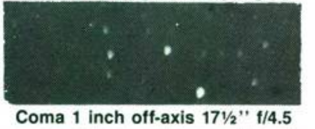
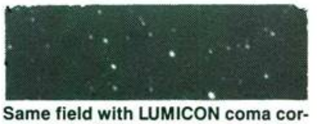


Coma 1 inch off-axis 17½'' f/4.5



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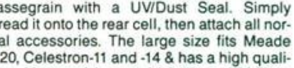

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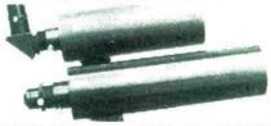

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, 45°version	$69.50
1¼'' straight-thru 80mm SUPER-FINDER	$199.50
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25mm Cross-hair 1¼'' eyepiece (12X)	$59.00
Large mounting rings for 80mm Finder	$55.00
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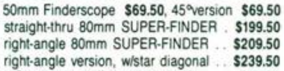

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser	4/$2		
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LUMICON carries a full line of telescopes and accessories. Fast Delivery, Competitive Prices.

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$129

ALWAYS GET THE BEST VIEW!

$99
(If ordered with LUMICON filter or filter set)

The New LUMICON Multiple Filter Selector holds up to 5 1¼" LUMICON filters. The sliding bar has a click-stop at each filter position. Now you can instantly select the best filter for any deep-sky object. Cost is $129 or $185 with 1.5X relay lens (for Newtonians). **Save $30 if ordered with filter(s)!**

TELE VUE™

NEW! Bino Vue Binocular Viewer

Genesis-SDF 4" f/5.4 apochromat	**$2125**
Pronto 70mm f/6.4 apochromat w/2" diagonal	**$969**
Pronto 70mm f/6.4 w/45° erecting prism	**$839**
NEW! Bino Vue binocular viewer	**$899**
Gibraltar mount with ash wood tripod	**$535**
10.4, 26mm Plossl 50°	**$79**
8, 11, 15mm Plossl . **$95**, 20, 25mm	**$105**
32mm Plossl, widest true field in 1¼"	**$125**
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2" Giant Barlow - 2x	**$185**
4.8mm Nagler, 82° field, 1¼" eyepiece	**$175**
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9mm Nagler, 82° field, 1¼" or 2"	**$245**
13mm Nagler, 82° field, 1¼" or 2"	**$315**
12mm Nagler, Type II, 82°, 1¼"/2"	**$295**
16mm Nagler, Type II, 82°, 1¼"/2"	**$315**
20mm Nagler, Type II, 82°, 2" only	**$395**
2" Paracorr Visual Coma Corrector	**$259**
15mm Panoptic 1¼", 68° field	**$215**
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TeleVue Warranty may not be valid outside USA.

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

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The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
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ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$189.50**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." ***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

BETTER THAN A DARK-SKY SITE!?

"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$79.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$199.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$199.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	**$399.50**
2" Rear Cell Filter, fits SCT's . Deep-Sky, **$199.50** UHC, O-III, H-Beta,	**$199.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Choice of ***any two*** LUMICON filters (**Save 7%**) . 1¼" **$185.00**; 48mm	**$370.00**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1¼" . **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines . 1¼" **$99.50;** 48mm	**$199.50**
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Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$7.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$19.50**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$25.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) Filter.

Specify Lens Size	**H-Alpha**	**(DS)**
46, 48, 49mm	**$59.00**	**$199.50**
52, 55, 58, 62mm	**$69.00**	**$199.50**
67, 72, 77mm	**$79.00**	**$399.50**
82mm (77mm + adapter)	**$89.00**	**$415.00**

Hypered 2415 film, 36 exp .. **$11.95, $3/$32**

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DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

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Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$109.50**

Guider for Hasselblad **$489,** Mamiya 645 **$259**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
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Pentax 6X7 **add $129;** Pentax 645 **add $149**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) .... **add $179.50**
Adapter for Hasselblad **$399,** Mamiya 645**$149**
Pentax 6X7 **add $139;** Pentax 645 **add $159**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** **$119.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.

2. **Cable release** for long exposures . **$9.95**

3. **Declination motor** (state telescope type) **$109**

4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.

5. **LUMICON EASY-GUIDER** (selection to left) .

6. **LUMICON 48mm DEEP-SKY FILTER $199.50**
This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.

7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

TRY PPF! HYPERSENSITIZED FILM

SR1600
Scotch
1000
TP 135-36

HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
Kodak PPF-400, THE BEST!	36	**$14.95**
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Gold 1000 fast, fine grain	12	**$13.95**
Fuji G800 fine grain color neg.	**24**	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

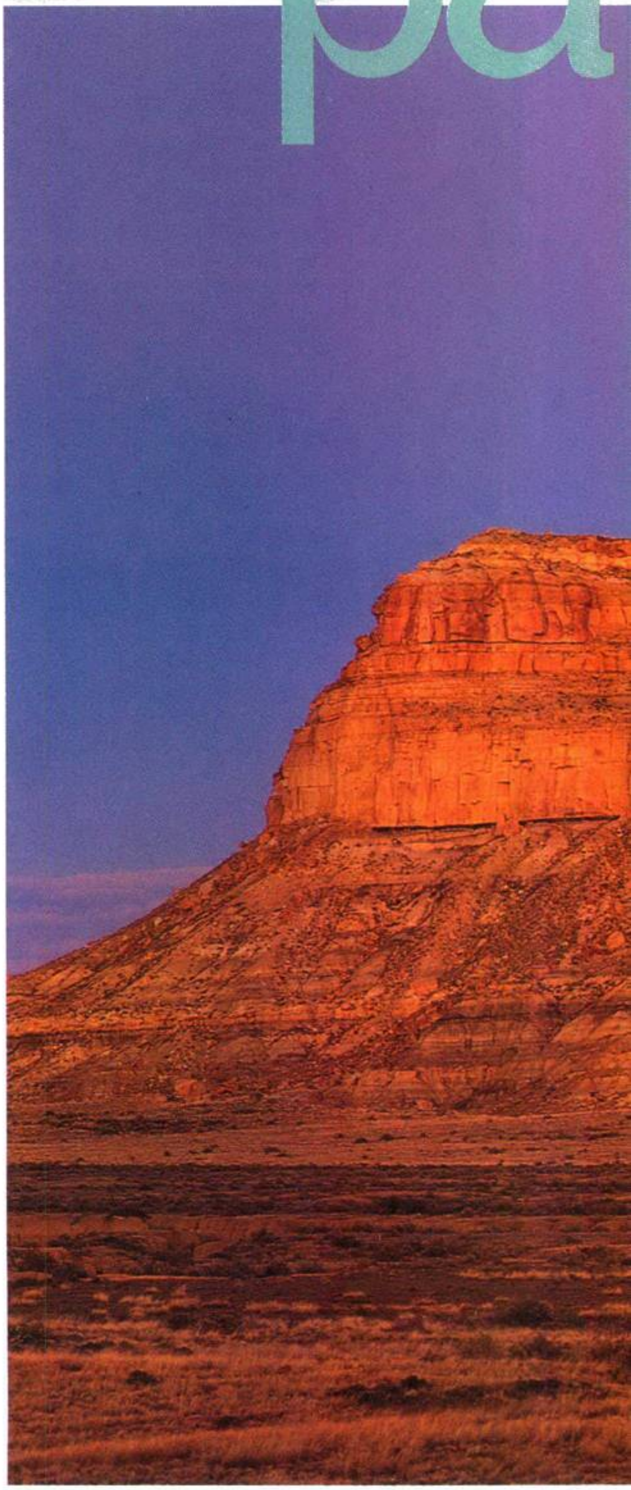
west pa

WHEN YOU CROSS THE SOUTHERN border of Colorado, a colorful sign that reads "Welcome to New Mexico: The Land of Enchantment" greets you. This phrase conjures up majestic mesas, Anasazi ruins, and adobe pueblos. Additionally, the skies — vast, blue, and clear — embrace the land in a never-ending dance of color. Miles of earth take on ever-changing hues, depending on the time of day or the status of the weather — always reflecting the mood of the sky above. It's no wonder that amateur astronomers flock to the Southwest. Not only is New Mexico a visual spectacle, but astronomy-related adventures abound — from professional observatories, prehistoric astronomy sites, and star-studded nights at an astronomical resort, to the town that provided fodder for *The X-Files* and *Independence Day* — New Mexico has it all.

Chaco Canyon — Lost in Time

Seemingly frozen in time, Chaco Canyon contains the largest collection of prehistoric ruins north of Mexico. It lies secluded in a barren and unforgiving environment where temperatures can plummet as low as –38° F in the winter and climb as high as 100° F in the summer. Vegetation in this stark but beautiful landscape is scarce, yet for hundreds of years, the Anasazi, ancestors of today's Pueblo Indians, lived and thrived here.

Ancient buildings and elaborate roadways suggest that the Anasazi must have had a rich culture, but the more artifacts archaeologists uncover, the tighter Chaco Canyon seems to hold on to its secrets. More than 3,600 archaeological sites are recorded within present park boundaries, but only one percent of them have been excavated. The community was clearly a center of bustling activity. From about A.D. 900 to 1115, people leveled fields and built complex irrigation systems. They constructed hundreds of impeccable stone-walled buildings and left nine multi-story structures, now called the Chaco Great Houses. They also built a massive road system that may once have extended as far north as the San Juan Range in the Rocky Mountains, as far south as the Mogollon Mountains, east to the turquoise mines near Santa Fe, and west perhaps as far as the San Francisco peaks near Flagstaff, Arizona.



Majestic Fajada Butte, bathed in moonlight, rises from the floor of Chaco Canyon.

A stargazer's haven, New Mexico offers an extravaganza of culture, history, art, and exquisite vistas.

by Patricia A. Kurtz

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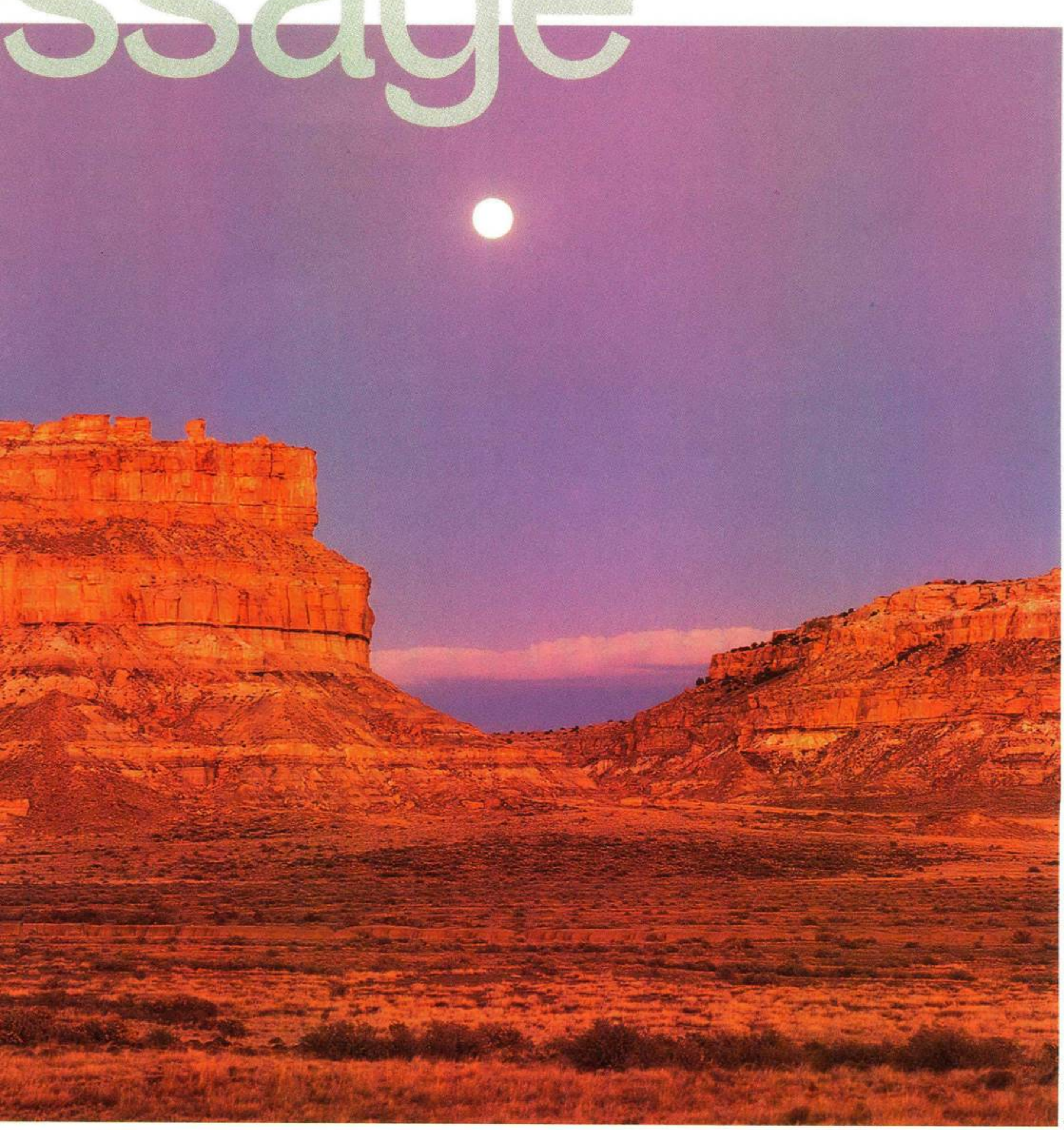
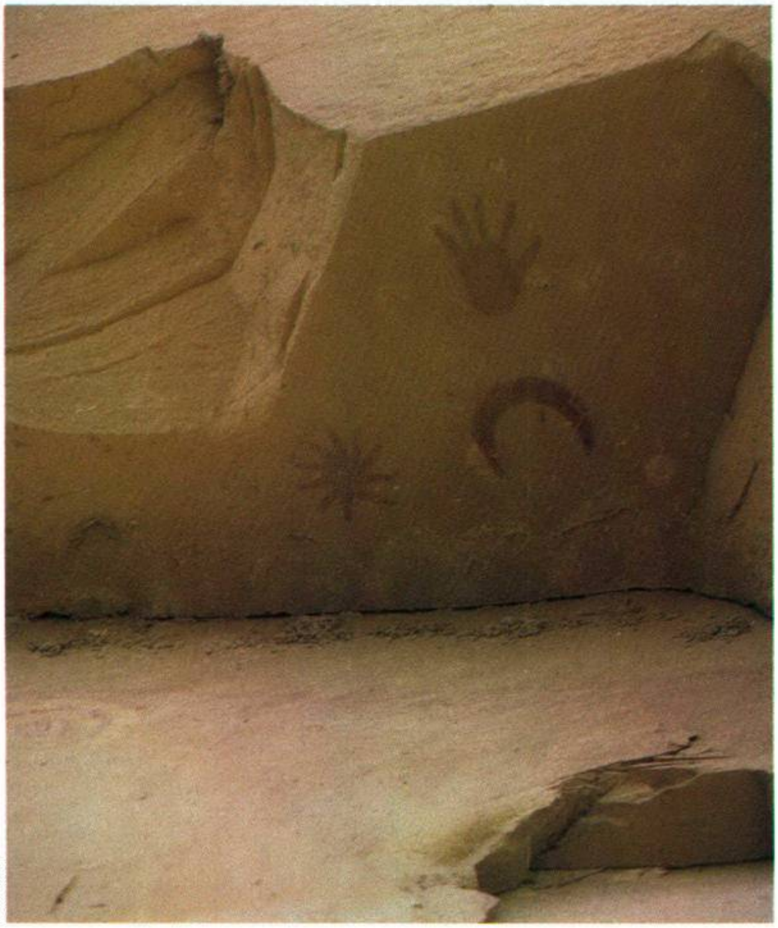


George H. H. Huey; Illustration: *Astronomy*: Elisabeth Rowan



Patti Kurtz

The crescent and star pictograph painted on an overhang at Chaco Canyon is thought to represent the supernova of A.D. 1054, which produced the Crab Nebula (M1). The wall of rock below the supernova portrays a comet-like object, perhaps recalling Comet Halley's visit in 1066.

But more than builders and farmers, the Anasazi were also astronomers. National Park Interpreter G. B. Cornucopia led us to several sites that appear to have been sun-watching stations of the "ancient ones." Scattered throughout the canyon, some leave traces no more revealing than the occasional petroglyph etched on a rock wall. Others, such as the controversial solstice marker located near the summit of Fajada (Banded) Butte, suggest a complex and involved study of the sky.

Rising 300 feet from the canyon floor, Fajada Butte is a dominant landmark at the southeastern end of Chaco Canyon. Near the summit of the butte on a June day in 1977, Anna Sofaer, an artist, was recording one of two spiral petroglyphs located on a rock wall behind three upright slabs of rock. At midday, she noticed a dagger of light slicing through the spiral. This apparent "sun dagger" falls on the spiral during equinoxes and both solstices. It may also mark the major and minor standstills of the moon. There is a great deal of controversy among archaeologists as to the dating and placement of this "sun dagger" site. Also, because the site has become increasingly fragile over the years, tourists are no longer allowed to climb to the butte's summit.

At the opposite end of Chaco Canyon, near the great house Penasco Blanco, is a breathtaking painting which many believe to represent the supernova of A.D. 1054, which formed the Crab Nebula (M1).

Standing beneath this pictograph, one can envision an ancient astronomer gazing up toward a star blazing next to a crescent moon in the twilight of dawn. What would the ancient one have thought, standing in what may have been a sun-watching station, on seeing an average, familiar star grow bigger and brighter than ever before, almost right before his or her eyes? This stellar event could be seen in daylight for three weeks. Adding yet another twist to the mystery is what appears to be a blazing comet etched into the rock wall beneath the "supernova" painting. The same sky-watching community could easily have added this feature with the visit of Comet Halley in 1066.

Though remote, Chaco Canyon is worth every bump and jolt on the rugged 17-mile dirt road that must be traveled to get there. Ladies, wear your sports bras for this ride. According to Cornucopia, "If you can get here, you can be here," is the motto of the National Park Service, caretaker of this exquisite monument lost in time.

In any event, Chaco Canyon is a compelling adventure that will have you creating your own ideas of what the Anasazi were up to. To see all there is to see, plan to spend two or three days here.

Camping is the best way to fully appreciate Chaco Canyon's wonders, unless you relish a 70-mile drive into Cuba, New Mexico, the closest place with plentiful accomodations, each night after exploring the ruins and trails all day. Besides, if you leave the park, especially from May to September, you'll miss great astronomy nights filled with telescopic tours of the universe. And under the jet-black skies of Chaco Canyon, the Milky Way stands out against the backdrop of stars like a ribbon of clouds dusted with sparkling glitter. What self-respecting observer would want to miss that? Bring a telescope or binoculars — you won't regret it.

But if you're like some people I know and have sworn resolutely never to camp again, the Chaco Inn at the Post — a bed and breakfast with three nice rooms and great food — is about 25 miles from the park in Nageezi. You'll definitely want to call ahead and make reservations, (505) 632-3646. Be sure to take your own food into the park because you won't find any at the informative visitors center, and carry lots of water with you. However you manage it, Chaco Canyon will deliver. Immerse yourself in the mystery of a genuine lost world.

Superintendent, Chaco Culture National Historical Park, P.O. Box 220, Nageezi, NM 87037; phone, (505)786-7014; website, http://www.cr.nps.gov/chcu/index.htm.

Roswell, New Mexico: Is the Truth Really Out There?

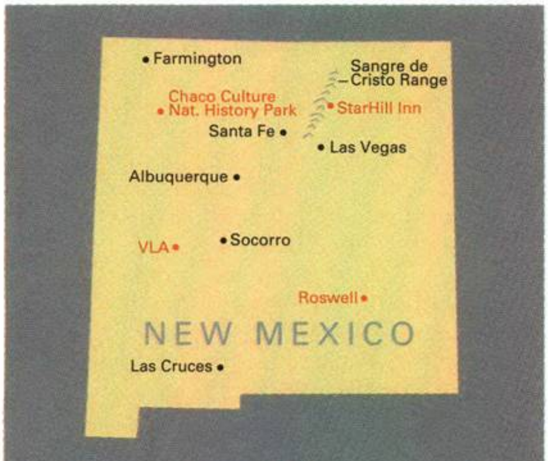
"We were in the back of my pickup truck, buck-naked . . . having a good 'ole time when about 11:30 the night of July 4, 1947, all hell broke loose.

"There was a big flash, an intense, bright explosion, with a noise like thunder, this thing came plowing through the trees, shearing off the tops, and then stopped between two huge rocks . . . the damn thing stopped about sixty yards from the pickup . . . we thought at first it was going to hit us!"

Okay. So this excerpt from *The Jim Ragsdale Story: A Closer Look at the Roswell Incident* is somewhat short of a documented, scientific report. Some of you are raising your eyebrows. What? An editor for *Astronomy* taking a joyride out to an alleged UFO crash site? Hey — it was on the way to the airport. And besides, the International UFO Museum and Research Center (IUFO MRC) at 400-406 N. Main Street in Roswell, New Mexico, has a great gift shop. The museum contains various displays including "Crop Circles: Phenomenon or Hoax?", "Ancient Cultures and Their Connections to Extraterrestrial Life Forms," and "The Mystery of Cattle Mutilations." Give IUFOMRC a call, (505) 625-9495, or check out their website, http://www.lookingglass.net/commercial/ufo/index.html.

In December 1996, the Tourism Association of New Mexico awarded the IUFOMRC its "Top Tourist Destination of New Mexico" award. Whether or not an alien spacecraft crashed outside of Roswell, the town has many attractions, both within the area and nearby, including the Kodak Albuquerque International Balloon Fiesta in October, Bitter Lake National Wildlife Refuge, Bottomless Lake State Park, and Carlsbad Caverns National Park. See Roswell's website at http://roswell-usa.com/ for upcoming events.

My traveling companion and I toured the museum and spoke with the delightful museum director Deon Crosby, who showed us pictures and gave us a map to the site where Roswell local Jim Ragsdale allegedly witnessed an alien spacecraft crash into the side of a mountain in 1947. We donned our *X-Files*, FBI-agent, Mulder and Scully hats and took the bait. It was, after all, just a couple months short of the 50th anniversary of the alleged "Roswell Incident."



New Mexico's astronomical attractions are scattered from Chaco Canyon and StarHill Inn in the north to the VLA in the west to Roswell in the south.

Roswell's Real Flying Objects

Long before the famed alleged UFO crash of 1947, strange objects whizzed about in the skies over Roswell. There were 56 in all, each well-documented, each uncontested. Though the man behind these gizmos did most of his work in secrecy, it was hard to hide the blasts and contrails coming from the local desert. These were the rockets of Robert H. Goddard.

From 1930 to 1941, the Goddards and their crew of four lived at Mescalero Ranch, just outside Roswell. They constructed a launch tower and a crude control shed and went about making giant advances in the science of rocketry.

Goddard built the first liquid fuel rocket in 1925, filled it with Texaco gasoline and liquefied oxygen, and set it off from a cabbage patch in Auburn, Massachusetts. When a *Boston Globe* headline read "'Moon Rocket' Man's Test Alarms Whole Countryside," Goddard began to realize the need to relocate. Thanks to supporter Charles Lindbergh, he received a large enough grant from the Guggenheim Foundation to head to the open spaces of New Mexico.

While there, Goddard made major advances in rocket propulsion, stabilization, tracking, and recovery. Thanks to parachutes sewn together by Mrs. Goddard, instruments could be placed in the nose cones and retrieved after the flight.

When visiting Roswell, stop at the Museum and Art Center. Goddard's launch tower sits on the front lawn, and a faithful recreation of his workshop waits inside. An extensive collection of rocket assemblies, patent applications, and documents spanning Goddard's career compliment the fragments of his first flight, also on display.

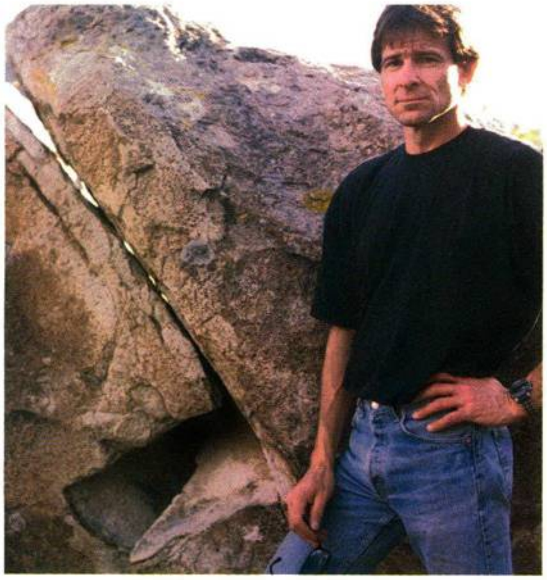
Admission to the museum is free, though contributions are appreciated. Located at 100 West Eleventh Street (Eleventh and Main), the museum is open Monday through Saturday, 9 a.m. to 5 p.m., and Sundays and holidays, 1 to 5 p.m.

— **Nancy L. Hendrickson**

Gary Becker

Star trails light up the dark skies above StarHill Inn, tucked away in New Mexico's Sangre de Cristo Mountains.

Following directions, we drove 51 miles west of Roswell on Pine Lodge Road toward Capitan and Boy Scout Mountains. The drive was beautiful as Capitan loomed ever closer in the late afternoon sunshine. After another five and a half miles or so on rugged dirt roads, we arrived at our destination. The boulders in question were easy to find because Crosby had shown us pictures of them before we left the museum.



Patti Kurtz

X-Files Fox Mulder impostor Kurt Vander Horst of Colorado investigates "evidence" of a UFO landing outside of Roswell, New Mexico. That the crack seen here was caused by the impact of an alien ship reputed to have landed 50 years ago remains unconfirmed.

The UFO supposedly crashed into the side of a mountain before slamming into three large boulders, stopping just short of Ragsdale's camping site. One of the boulders was supposedly split by the impact. I'm no geologist, but I did meticulously photograph the boulders in question. Was the boulder split by an impact, or could it have been a more natural event, such as water seepage? The site didn't appear extraordinary — apart from the split boulder, it was a lovely forested hill. Here and there we saw a downed tree, but no more than one finds on any camping excursion.

Not wishing to be a stick-in-the-mud, when I returned home I turned my photographs over to geologist Herman Bender of Fond du Lac, Wisconsin. His verdict? Though he stated that an on-site visit would be necessary for total confirmation, on studying the photos, he felt the crack in the boulder was a result of a natural process, probably seismic. The surface of the rock inside the crack, he thought, showed weathering and exfoliation in excess of the 50 years since the purported impact — more likely thousands of years.

Did an alien spaceship crash into a mountain hillside on a thunderous July night in 1947? Did the United States government confiscate that spacecraft and then undertake a monumental effort to cover up any leftover evidence? I'll let you draw your own conclusions. For my part, I say no. But darn it all, I wanted to believe.

StarHill Inn

Mystical and magical, a stop at the world-renowned StarHill Inn is a vacation in itself. People have traveled from as far away as Singapore to experience the velvet black skies of the Southwest coupled with the warm hospitality of Phil and Blair Mahon, owners and operators of this star-gazing getaway. Nestled deep in the Sangre de Cristo Mountains in the northern part of New Mexico, StarHill Inn has provided an astronomical extravaganza for amateurs and professionals alike since 1988. But it charms more than just those who love the dark. Daylight is delightful, and the sun rises to the melodies of 300 or more bird species who call the area home.

With two national wildlife refuges (Las Vegas and Maxwell National Wildlife Refuges) and two state parks in the immediate vicinity, it's easy to see why StarHill Inn provides birding workshops on its menu of activities. The inn also provides a map of birding spots in the area, and Blair is always willing and eager to share her birding adventures with others.

StarHill Inn is not only a birders' paradise; hikers can trek for months without repeating a trail. And should you tire of StarHill's 195 acres of ponderosa forests and mountain meadows, just drive to a trailhead in the Pecos Wilderness. More than 200,000 acres of woods, wildlife, and mountain peaks climbing to 13,000 feet are yours to explore. If the season's right, areas to hunt, fish, and boat are just minutes away.

New Mexico's abundant opportunities for exploring ancient Native American pueblos and cliff dwellings are nearby as well — Bandelier, Puye, Pecos, and Tsankawi are all between 45 minutes and two hours away.

And, of course, the lure of Santa Fe is hard to ignore. About an hour's drive southwest, its history, downhill and cross-country skiing, musical festivals, pueblos, and numerous art galleries and shopping opportunities make it a must on any New Mexico adventure list.

But if you're one of those single-minded, die-hard, detect-faint-celestial-targets-'til-you-drop types, you will not be disappointed. With only a small light-dome visible to the southwest (Las Vegas — no, not the gambling mecca of Nevada, but New Mexico's own), the limiting magnitude at StarHill Inn is 6.5. Powered piers for seven telescopes command the observing deck, which is adjacent to the library/warming house and observatory dome.

Bring your own observing equipment or rent one or more of the many on-site telescopes, binoculars, and accouterments. From 7x42 binoculars to a 24-inch f/8 Ritchey-Chrétien scope with an ST-8 CCD camera, the selection should satisfy star-gazers at all levels of expertise. You can also opt for a private observing session and sky tour with Phil using your choice of nine telescopes. The sky's the limit for relaxed or serious observing, astrophotography, and even armchair astronomy. If the night clouds over, the library holds a television, videocassette recorder, videos, books, and a computer loaded with *TheSky* (Software Bisque), *Earth-Centered Universe* (Nova Astronomics), and *Distant Suns* (Virtual Reality) software.

Nazca in New Mexico?

Fred Espenak

Looking like a modern-day version of the Nazca lines in Peru, the Very Large Array (VLA), 50 miles west of Socorro, is one of the world's foremost astronomical radio observatories. Shaped in a huge Y-pattern up to 22 miles across, the VLA consists of 27 antennas with the power to resolve a golf ball at 100 miles away. Each antenna is 81 feet in diameter and weighs 230 tons.

Astronomers all over the world use the VLA, which is operated by the NRAO, a facility of the National Science Foundation. The visitor center is open to the public from 8:30 a.m. until sunset daily, year-round.

Don't feel like observing? Simply relax in one of StarHill Inn's seven extraordinary cottages for the evening. Impeccably decorated and immaculate, the Mahon's love of this celestial retreat shines in each and every detail. All units boast a fully equipped kitchen stocked with staples (including a toaster-oven, coffeemaker, and coffee), a beautiful and distinct fireplace for those cooler nights, a private porch, and a lovely bath. When it's time for bed, snuggle up under the colorful, fluffy comforters, turn off the lights, and gaze at the delicate array of stars painted on your ceiling.

Whether you take your family, a friend, or travel alone, there is something for everyone at StarHill Inn. Be sure to call for a schedule of upcoming workshops, including those on visual astronomy, ancient astronomy, and astrophotography. This retreat could easily justify an entire holiday, but it can also complement your vacation if you're just "passing through." Whatever you do though, don't pass it by.

StarHill Inn, P.O. Box 1A, Sapello, New Mexico 87745; phone, (505) 425-5605; e-mail, starhillinn@nmhu.campus.mci.net; website, http://www.starhillinn.com.

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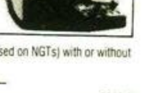

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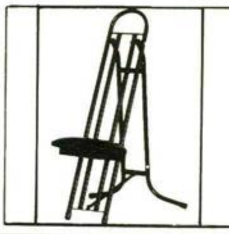

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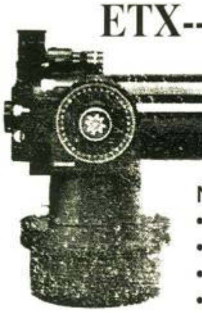

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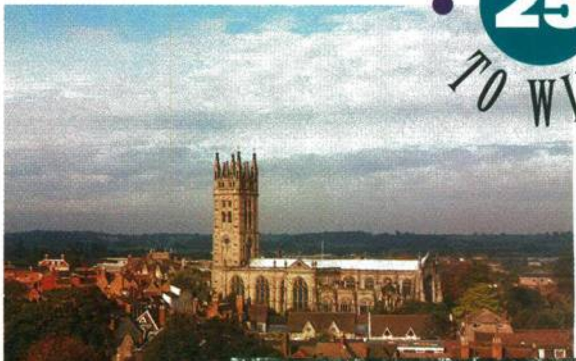

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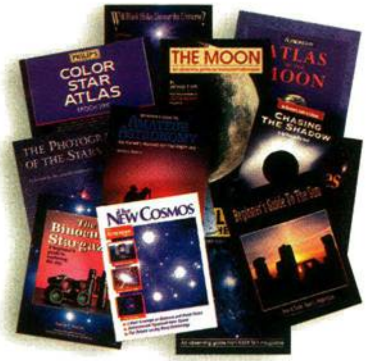

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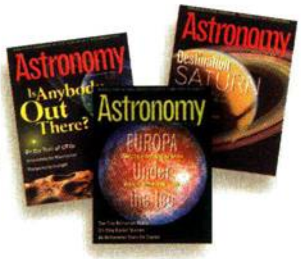

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ask Astro

Using hypered film allows astrophotographers to capture more vivid colors and details, as seen in this photo of spiral galaxy M81. Tony and Daphne Hallas

Q: Faced with no alternative, I use one-hour photo stores for my hypered film, though I know it's not advised. One such store developed my hypered Kodak PPF 400 film but said it couldn't be printed because there was nothing but dots. At another one-hour store, the prints came out with a sky that was green instead of black. Is there anything I can do? — *Bob Lyons, Monroe, New York*

A: There is indeed something you and others can do to help the one-hour lab achieve some decent results with any film that has been exposed under the night sky: Bring some samples with you to the lab. If you have shot galaxies, show them a few samples from an astronomy magazine. Ditto with nebulae and star fields. Explain to them that the film might require some strange filtration during printing because it's a special astronomy film but that it should be possible for them to print. Tell them that you would like a neutral black sky, and if you have some faint stuff on the negatives, you'd like the sky to be a neutral gray because you want to see everything on the negative (printing it black would obliterate the faint stuff). If need be, tell them that you are willing to pay $10 extra for their extra time and materials to adjust the prints to look like the samples (fair is fair). Any lab worth its developer can match a sample as long as they have some idea of what the final image is supposed to look like.

One word of warning: If you are shooting single negatives, don't show them a super-enhanced version of what you have. If you do, warn them not to expect results as vivid as the sample.

If all else fails and you are sure you have some decent negatives, send them to Astro Photo Lab, 165 Alto Drive, Oakview, CA 93022, and we will try to make the best prints possible from your negatives. — *Tony Hallas, Astro Photo Lab*

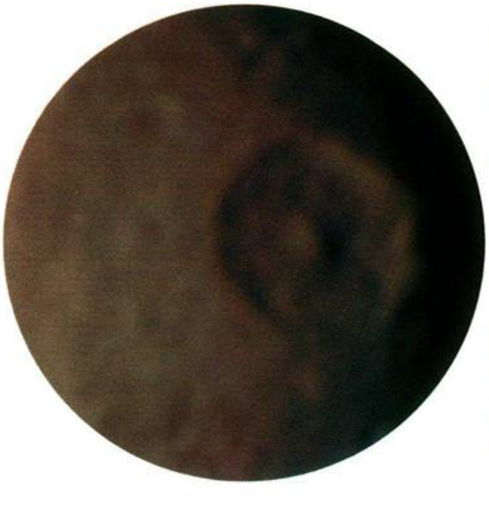
Q: If stars undergoing nuclear fusion combine lighter elements into heavier ones but stop at iron, why do we have elements heavier than iron here on Earth? — *Susan Maes, Manitowoc, Wisconsin; Eugene L. Hayman, Jr., Deer Park, Texas; Harold W. Jones, Sperryville, Virginia; and Gene Lee, Plano, Texas*

A: The major fusion reactions in stellar cores that turn hydrogen (element 1) into helium (2), then helium into carbon (6) and oxygen (8), and in massive stars even heavier elements such as silicon (14) into iron (26), release energy that stabilizes the stars and keeps them from collapsing under gravity (see "Creating Heavy Elements," page 44). A huge number of other reactions which do not involve main energy production, however, can take place as well, those involving heavy elements absorbing energy.

When low-mass stars (below about 10 solar masses) are in their giant phases, free neutrons released during helium burning can be captured leisurely by atoms heavier than iron. The resulting element is often unstable, and a neutron can eject an electron and become a proton, thus increasing the element's atomic number. Neutron capture and subsequent radioactive decay create elements all the way up to bismuth (element 83). Good examples of elements produced in this manner are strontium (38), zirconium (40), and tin (50). These atoms are released into the cosmos by stellar winds.

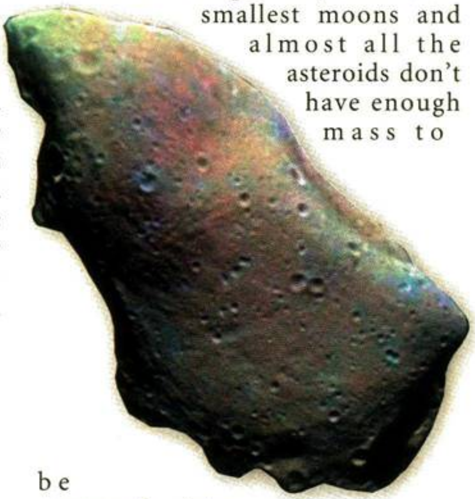
In massive stars (above about 10 solar masses), the collapse of the iron core during a supernova produces a nuclear cauldron in the heat of the resulting detonation. These reactions (which include explosive burning and rapid neutron capture) produce a huge range of elements, from those lighter than iron all the way up to heavyweights such as uranium (92) and even plutonium (94). — *James Kaler, University of Illinois*

Saturn's moon Mimas (below), with a diameter of 244 miles (392 km), is one of the smallest spherical objects in the solar system. But asteroid Gaspra (right), only 12 miles (19 km) long, doesn't have enough mass to become a sphere. NASA/JPL



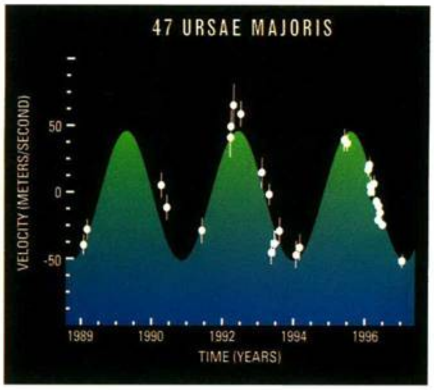
Q: If the Big Bang really happened and the dust and debris finally settled to form stars and planets, why are they all round in shape? Shouldn't they appear in irregular shapes? — *Kok Leong Yee, Singapore*

A: No. The reason why stars, planets, and the largest moons and asteroids are round can be summarized in one word: gravity. Gravity tries to pull all of an object's mass toward the center, so gravity will always compress a fairly massive object into a sphere. (Because objects in space rotate, they generally have a slight equatorial bulge; Jupiter and Saturn being prime examples.) In our solar system, every object more than 200 miles (320 km) across is spherical, whereas the smallest moons and almost all the asteroids don't have enough mass to be squeezed into a sphere, so most of these objects are non-spherical. — *Robert Naeye*



Q: When a new planet is announced around a sun-like star, a minimum mass and distance is usually specified. How can both of these factors be determined at the same time? Isn't there a range of possible masses depending on the orbital radius? In other words, wouldn't a planet with one-quarter the mass at half the distance have the same effect as a larger one at twice the distance? — *Ed Moder, Burr Ridge, Illinois*

A: The short answer is no. The Doppler velocity data we obtain immediately tells us two things: the planet's orbital period and the speed at which the star is moving toward and away from Earth due to the gravity of the unseen planet. Knowing just the period, we can calculate the orbital distance using Kepler's third law of planetary motion. Knowing the orbital distance and the period, we calculate the orbital speed of the planet (speed = 2 x π x distance/period).



In this plot of the planet orbiting 47 Ursae Majoris, the spacing between wave crests tells astronomers the orbital period of the planet, from which astronomers can easily calculate the approximate distance of the planet from its host star. The height of the wave crest enables astronomers to calculate the planet's minimum mass. Geoff Marcy and Paul Butler (San Francisco State University)/*Astronomy*: Elisabeth Rowan

At this point we know three things: the approximate mass of the star to within a few percent (because all of our target stars are similar to the sun), the observed Doppler velocity of the star due to the planet's gravity and orbital motion, and the orbital velocity of the planet. From these, astronomers apply the principle of momentum conservation to calculate the minimum mass of the planet (star's mass x star's velocity = planet's mass x planet's velocity). Because we do not know the inclination of the planet's orbit with respect to our line of sight, we can only calculate the planet's minimum mass.

To learn more about our planet search, go to http://cannon.sfsu.edu/~williams/planetsearch/planetsearch.html. — *Paul Butler, San Francisco State University*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53186. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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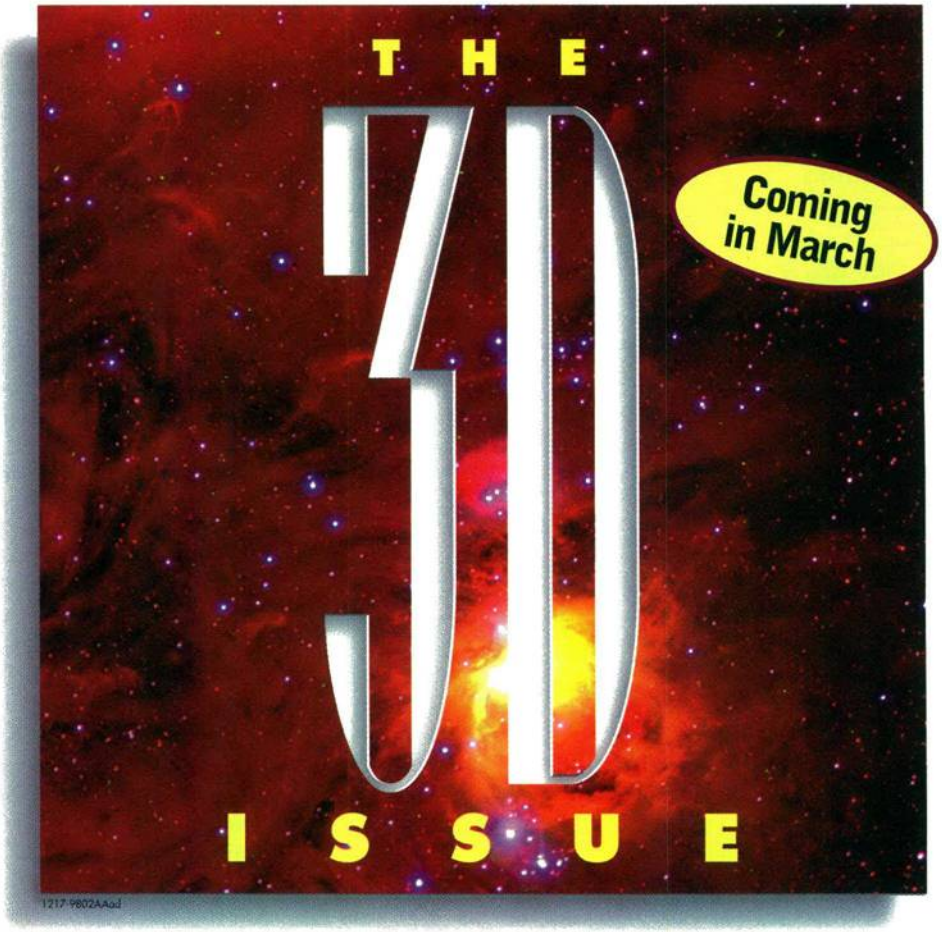

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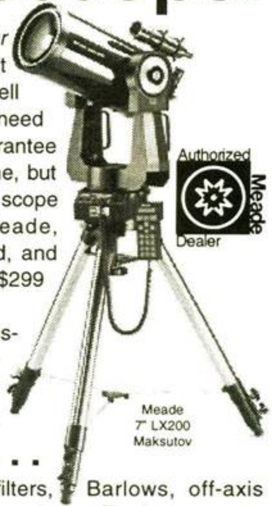

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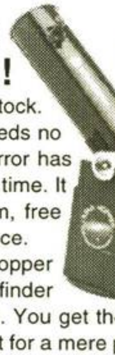

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We keep Celestron's 8" **Star Hopper** in stock. It's an advanced Dobsonian reflector that needs no tools for collimating its optics and whose mirror has 40% lower thermal mass for faster cooldown time. It comes with a unique built-in balance system, free collimating eyepiece, and 25mm (49x) eyepiece.

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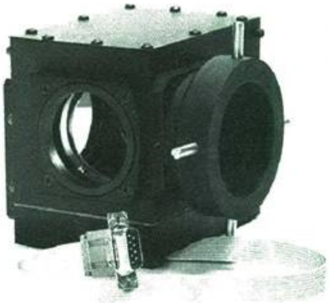
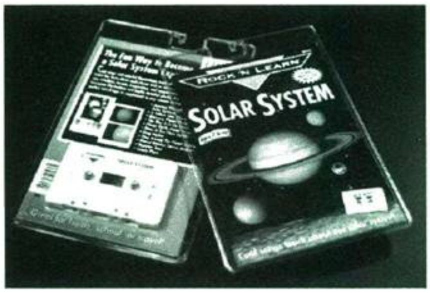
PRODUCTS

Model AO-7 Adaptive Optics System



▶ SBIG is proud to announce the arrival of the *Model AO-7* adaptive optics system, which incorporates adaptive optics with CCD imaging. Specifically designed to enable an ST-7 or ST-8 user to obtain the ultimate in image resolution, the *Model AO-7* takes advantage of the second guiding CCD detector in these imaging cameras in order to stabilize stellar images and enhance resolution. Two components, a high-speed tip-tilt mirror system for atmospheric correction and new image enhancement software implementing the Lucy-Richardson algorithm, make this product unique. The tip-tilt mirror moves and settles to within 20 percent of the commanded position in 10 milliseconds, faster than any telescope drive. The image enhancement software, using algorithms similar to those used on Hubble Space Telescope images, produces dramatic improvement in image detail — at least a twofold visual improvement.

Santa Barbara Instrument Group, 1482 East Valley Road, P.O. Box 50437, Santa Barbara, CA 93150; phone, (805) 969-1851; fax, (805) 969-4069; e-mail, sbig@sbig.com; website, http://www.sbig. com. *Model AO-7*: $800.



Solar System Audio Tape

▶ Manufactured by Rock 'N Learn and distributed by Latz Chance Games, Inc., *Solar System* puts the facts and information of the solar system to music, making it fun and easy for kids to learn. Using cool songs and rap, the *Solar System* audio tape teaches kids the order of the planets and facts about each one, such as size, distance from the sun, satellites, terrain, composition, and temperature. Each planet gets its own song, as does the sun. The tape is accompanied by a book of lyrics so kids can sing along, and the book is enhanced by great illustrations and NASA photos. For kids ages seven and up, *Solar System* makes a perfect travel tape, serves well as music for astronomy theme parties, and is a great supplement to any science curriculum.

Latz Chance Games, Inc., P.O. Box 72308, Marietta, GA 30007–2308; phone, (770) 579-6173; fax, (770) 565-2756. *Solar System*: $9.95.

BOOKS

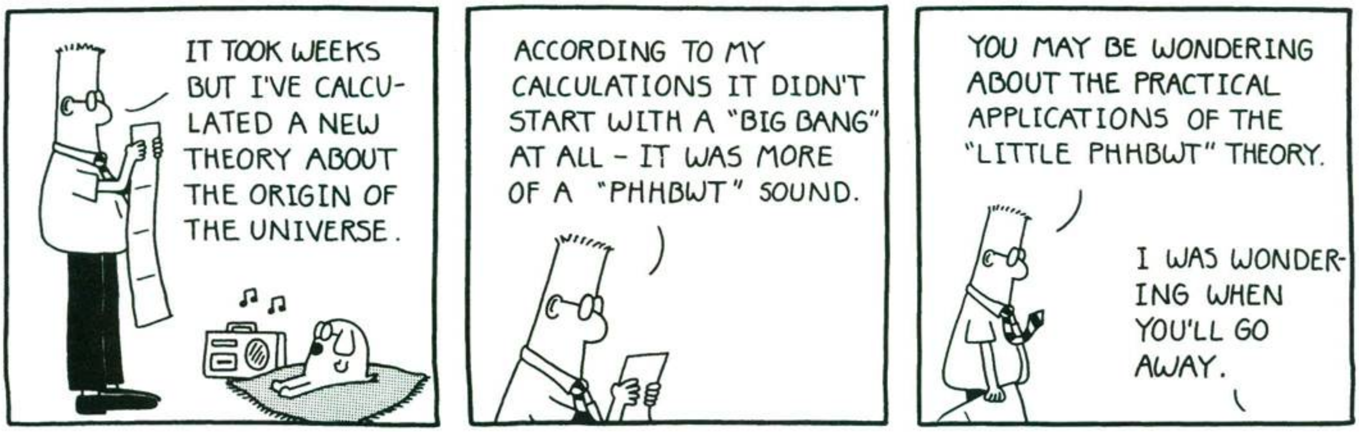
Portraits of Discovery

George Greenstein, 232 pages, John Wiley and Sons, New York, 1997; ISBN 0-471-19138-8; hardcover, $24.95.

▶ Some activities are uniquely human — music, for example. We know that crickets do not "hear" any of the haunting moonlight serenades that we find so evocative; the vibration produced by the snapping of one cricket's legs merely causes other crickets nearby, through thinnings on their front knees, to feel like twitching and moving in certain stereotyped ways. Even songbirds are unable to experience music as we do. We alone have brains able to manipulate simultaneous tones into intervals, chords, and harmonic progressions, then to build these fragments into fetching melodies and ultimately into massive, cathedral-like edifices of spellbinding sound.

Musical appreciation is obviously something that is almost universal among us. Nevertheless, there have been only a few brains able to create music at the highest levels — brains belonging to genius-composers like Mozart, musical meta-magicians whose powers are incomprehensible to the rest of us.

Like music, science is also a uniquely human activity. Of all the species on Earth, only *Homo sapiens* "do" science. The human dimensions of this activity are not always emphasized in science writing, however, which too often refers to scientific data and knowledge as if it existed independent of the relatively few


IT TOOK WEEKS BUT I'VE CALCULATED A NEW THEORY ABOUT THE ORIGIN OF THE UNIVERSE.
ACCORDING TO MY CALCULATIONS IT DIDN'T START WITH A "BIG BANG" AT ALL - IT WAS MORE OF A "PHHBWT" SOUND.
YOU MAY BE WONDERING ABOUT THE PRACTICAL APPLICATIONS OF THE "LITTLE PHHBWT" THEORY.
I WAS WONDERING WHEN YOU'LL GO AWAY.

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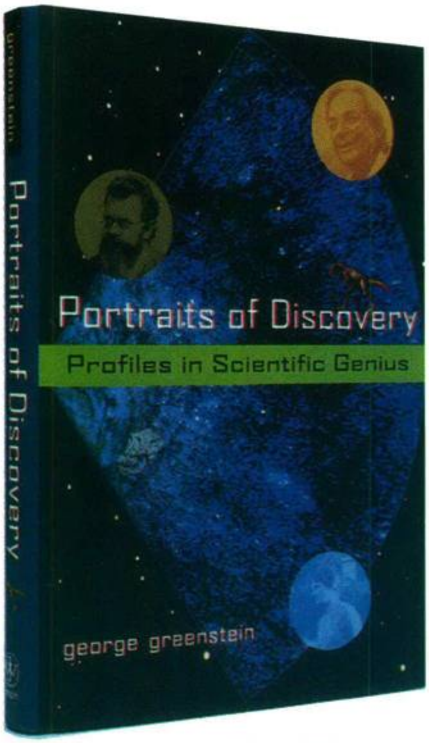
humans who fashion it and the larger (though still disappointingly small) number of humans who appreciate it. For instance, most pictures of Earth from space are presented as "objective" data, even though they originate, as astronaut Story Musgrave puts it, "when some human is sticking his or her nose in the window and sees something that causes him or her to react: 'Wow!'"

George Greenstein, a professor of astronomy at Amherst College and a prize-winning science writer (he won a Phi Beta Kappa award for his earlier book *Symbiotic Universe: Life & Mind of the Cosmos*), has offered a book full of tantalizing insights into the often-neglected human side of science. He presents ten profiles of noted scientists. All are recent figures, one or two from the 19th, the rest from the 20th century; all have been major innovators. He has chosen these scientists not exclusively for their scientific importance but because of the interest of their personalities and the unique niches they have filled within the larger human story of science. What he has produced is a gallery full of fascination, an engaging perspective on what Pascal once called "the glory and misery of man." Most of the figures profiled here are well known, their lives extensively documented in autobiographical writings and, in some cases, full scholarly biographies. Nevertheless, no one can fault Greenstein for his choices. Most of the scientists whose lives he relates were eccentrics; some were seriously flawed as human beings. All were passionate and tireless in their dedication to science.

We meet bongo-drum playing Richard Feynman, a scientific "magician" of the highest caliber whose scientific work, Greenstein says, had an almost Mozartean quality. But we also learn that Feynman was a compulsive showman — hence the bongo playing — who self-consciously developed his reputation as the perpetual adolescent and buffoon. We learn of his brilliant scientific work but also of his tragic marriage (his wife developed cancer and died early) and of his later compulsive sexual escapades.



We meet Ludwig Boltzmann, the brilliant 19th-century physicist, who did as much as *anyone* to establish the atomic theory but who suffered from manic-depressive illness and hanged himself in 1906 just as the atomic theory he fought for was on the verge of ultimate vindication. Some of the personalities presented here, such as George Gamow and Luis Alvarez, are well-known; others are less familiar.

Greenstein's writing has a conversational and at times rambling quality, appropriate to his mission as a storyteller. I found frustrating the fact that he sometimes mentioned brilliant work without attempting to give even rudimentary explanations of what it was about; at other times, as in his discussion of spectroscopy in the essay on Cecelia Payne-Gaposchkin, he seems to imply no previous knowledge on the part of the reader, and the tone becomes mildly patronizing. He makes many references to scientists that are unnecessarily vague and elliptical. For instance, instead of simply and clearly identifying E. C. Pickering by name, he chooses to refer to him as "the director of the Harvard Observatory in 1894." In general though, his writing is elegant, his account rich with anecdotes.

The personalities that emerge from these essays remain, at bottom, enigmatic. Many of these people seem to have been rather formidable, intimidating figures. I didn't get the impression that I would have gotten on very well with most of them. Perhaps this is inevitable; the creative reaches of people who perform science at the level of a Boltzmann or a Feynman stand immeasurably beyond the range of the rest of us — they are Mozartean, "magician-like."

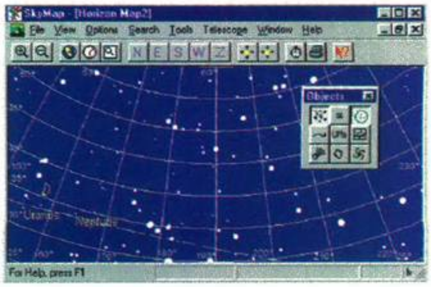
Still, we must continue to make the effort to bridge the gap between the achievements of the "magicians" who create and the abilities of the rest of us to comprehend: Our very survival on the planet depends on it. In order for science to realize its potential, it must not only cater to our material comforts but must enter into our choices about the present and the future, which means it must enter more fully into our ethical development as well. But then it cannot remain the province of a few. Like music, it must come to live in the very marrow of our bones. Instead of seeming like magic, science must wear a human face. — *William Sheehan*

A BYTES

SkyMap 3.1

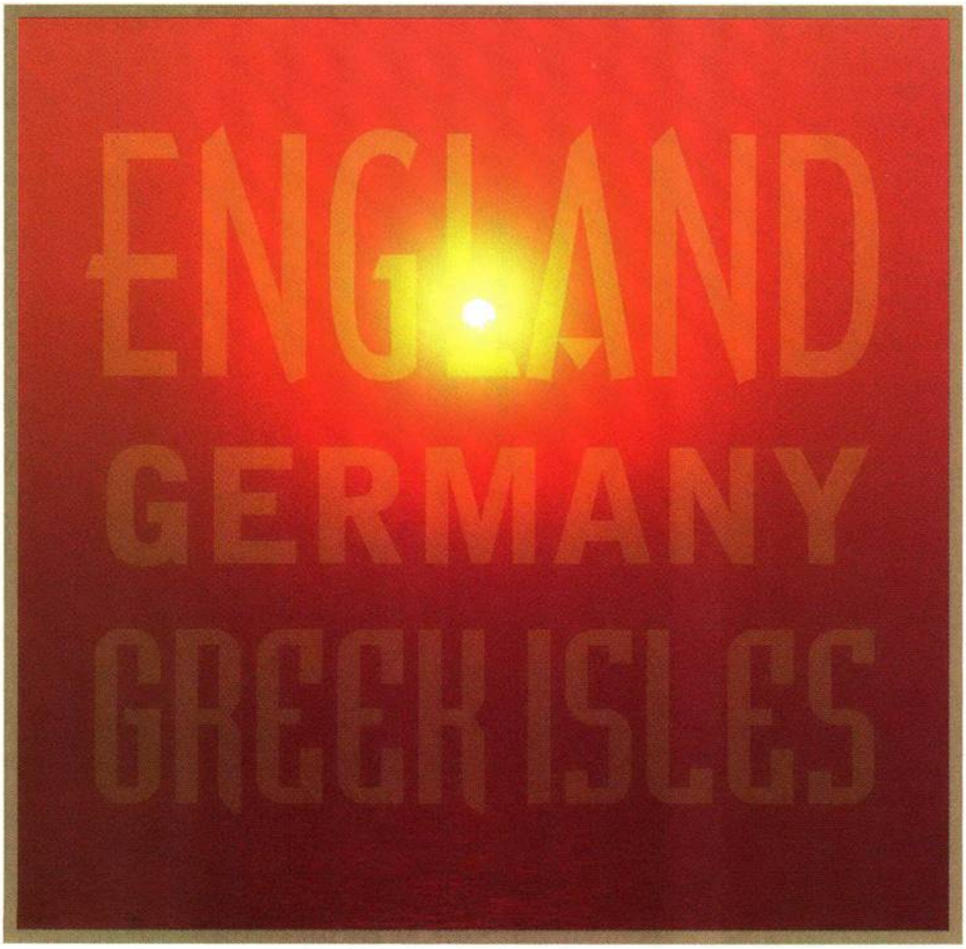
▶ A new and improved version of SkyMap from JASC, Inc. has recently been released. *SkyMap 3.1* builds on the strengths of the original version, SkyMap, a planetarium software program which displays extremely accurate maps of the sky from any point on Earth for any date between 4000 B.C. and A.D. 8000. But *SkyMap 3.1* goes further to provide both a horizon map showing a local view of the sky as seen by an observer, and an area map, offering a detailed view of a small area of sky. The program also employs extensive search functions; any object in the databases can be quickly and easily located with just a catalog number or popular name.

The program includes a catalog of 88,000 stars to magnitude 8.5. The complete SAO catalog of 259,000 stars to magnitude 9.5 is available as an add-on



Astronomy Magazine presents

1999 solar eclipse tours



Come join ***Astronomy*** Magazine on one of their four amazing solar eclipse tours being held August 6-15, 1999. Along with catching one of the most spectacular views of the last solar eclipse of the 20th century, you will experience the magnificent sights and sounds of such wonderful places as England, Germany, and the Greek Isles in the process. Choose your favorite destination today.

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GERMANY—You'll begin your tour in Munich, the city of festivals, and will help celebrate the special German Festival of the Eclipse. Visit the beautiful Alps, as well as many castles, planetariums, and observatories as you travel along the path of the eclipse.

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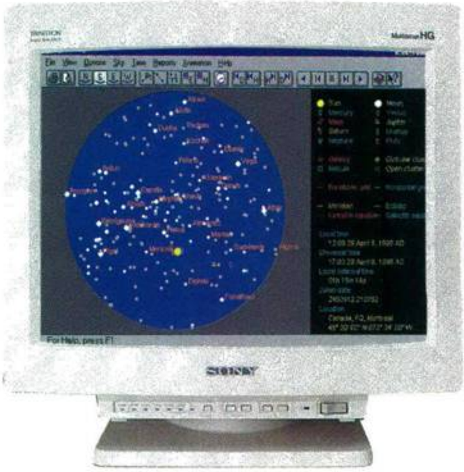
option. In addition to the stars, *SkyMap 3.1* also displays the sun, moon, and all the planets. Clicking on any planet brings up detailed information including positions, phases, visual magnitudes, and light-time distances. Users can add to, edit, and delete from catalogs of comets, asteroids, and non-stellar objects (including galaxies, clusters, and nebulae), and the names, figures, and official IAU boundaries of all 88 constellations can be displayed. Perhaps most useful of all, any map of the sky that you bring up can be printed easily, and the printed maps hold their own against high-quality star atlases.

JASC, Inc., P.O. Box 44997, Eden Prairie, MN 55344-0997; phone, (800) 622-2793, (612) 930-9172; fax, (612) 930-9800; e-mail, sales@jasc.com; website, http://www.jasc.com. Price: $49. Minimum requirements: Windows 95 or Windows NT.

CyberSky

▶ Pick a date, set a time, choose a location, and *Cybersky* will set to work displaying stars, constellations, planets, deep-sky objects, the sun, and the moon on your computer screen. The sky can be displayed in either a planetarium view, as it would be projected on a planetarium ceiling dome, or in a horizon view, showing a more detailed view along the



horizon; the sky is displayed in full-screen size to take advantage of your monitor's display area. Any date between 4000 B.C and A.D. 4000 is yours to choose.

An important feature that sets *Cybersky* apart from other planetarium programs is its ability to show "movies" of the changing appearance of the sky over time using computer animation. You can move forward or backward at varying speeds and watch the course of the stars and planets. Operating this function is as easy as operating your VCR at home. In fact, everything about the Cybersky program is designed with point-and-click ease in mind. A toolbar at the top of the screen offers several additional options, such as pull-down screens with information on the phases of the moon, the positions of the planets, and the position of the sun. All colors and fonts can be customized to your liking, and sky charts can be output on any printer.

Stephen Michael Schimpf, 2444 West 230th Street, Torrance, CA 90501-5242; e-mail, CyberSky@compuserve.com; website, http://cybersky.simplenet.com/. Price: available for downloading on the Internet, $12 upgrade for previous *Cybersky* users. Minimum requirements: Windows 3.1 or Windows 95. ■

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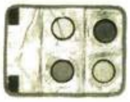

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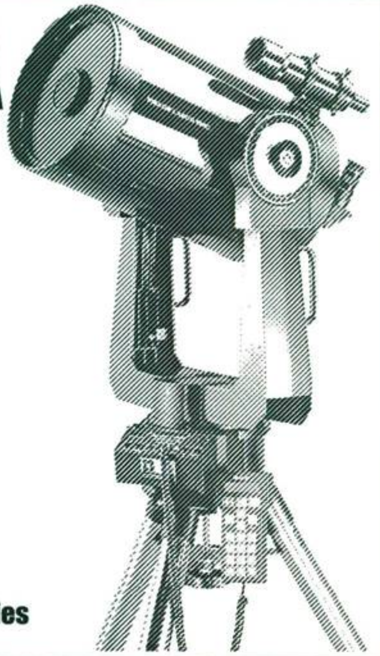

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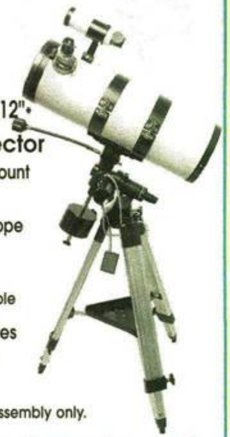

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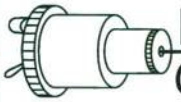

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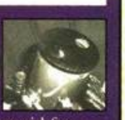

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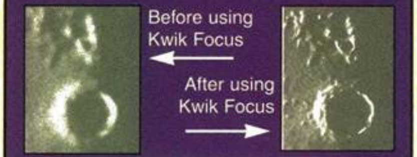

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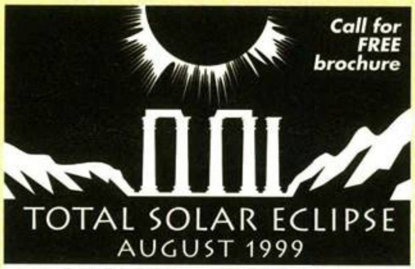
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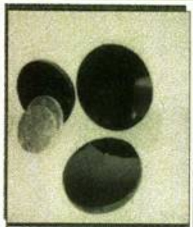
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Conversation at any gathering of astronomers will be sure to include the solar eclipse taking place in the Caribbean on February 26. If spur-of-the-moment travel is your cup of tea, don't hesitate to look into opportunities for last minute specials with your travel agent so you, too, can experience this celestial event.

Pre-registration has begun for the **Texas Star Party**, one of the largest gatherings of amateur astronomers in North America. It will be held **April 19–26** on the mile-high Prude Ranch near Fort Davis, Texas. Contact the TSP Registrar at 1326 Mistywood Lane, Allen, TX 75002, or check the TSP website for full details, http://www.metronet.com/~tsp/index1.html.

For a listing of other important events, including *Astronomy*'s 25th anniversary star party taking place in Albuquerque, New Mexico, this coming June, see *Astronomy*'s website, http://www.astronomy.com.

JANUARY 26–FEBRUARY 1

Winter Star Party

▶ West Summerland Key, Florida Keys. Sponsored by the Southern Cross Astronomical Society. Contact Mike Barrs, 3403 Poinciana Avenue, Miami, FL 33133; (305) 441-2428; e-mail, wsp@scas.org; website, http://www.scas.org/wsp.html; accommodations info, (800) FLA-KEYS.

JANUARY 29–FEBRUARY 1

The Orange Blossom Special Star Party

▶ Hickory Hill Observing Complex, near Brooksville, Florida. Sponsored by the St. Petersburg Astronomy Club. Contact Dennis and Ellen Farr, 8811 West Broad Street, Tampa, FL 33615; (813) 884-9111.

FEBRUARY 7–8

Northwoods Winter Starfest

▶ Hobbs Observatory, near Fall Creek, Wisconsin. Sponsored by the Chippewa Valley Astronomical Society. Contact Ray Forsgren, 4856 Inlet Drive, Chippewa Falls, WI 54729; website, http://www.phys.uwec.edu/cvas/.

FEBRUARY 21–28

Astronomy's Total Eclipse Cruise

▶ View the Caribbean's total solar eclipse with the *Astronomy* editors on board Celebrity Cruise Line's newest ship, the *Galaxy*, sailing from San Juan, Puerto Rico. For more information, contact Specialty Tours, 2701 Sunset Point Road, Clearwater, FL 34619; (800) 677-9412 or (813) 796-7555.

FEBRUARY 26–MARCH 1

Highlands Stargaze

▶ Nine Mile Grade Campground, Sebring, Florida. Contact Richard Lindblom, 2130 Gresham Street, Sebring, FL 33872; e-mail, lindblom@ct.net; website, http://www.cris.com/~Lindblom/Index. shtml.

MARCH 7

Wagman Winterfest

▶ Nicholas E. Wagman Observatory, Mahaffey Road, Deer Lakes Regional Park, Russellton, Pennsylvania. Free. Contact Pete Zapadka, (412) 224-2510; e-mail, pzapadka@fyi.net; website, http://trfn.clpgh.org/orgs/aaap.

MARCH 16–20

Lunar and Planetary Science Conference

▶ NASA Johnson Space Center, Houston, Texas. Cosponsored by the Lunar and Planetary Institute and the NASA Johnson Space Center. The meeting will focus on new results in planetary science. Contact LeBecca Simmons, 118 Publications and Program Services Department, 3600 Bay Area Boulevard, Houston, TX 77058-1113; (281) 486-2158; e-mail, simmons@lpi.jsc.nasa.gov.

MARCH 21

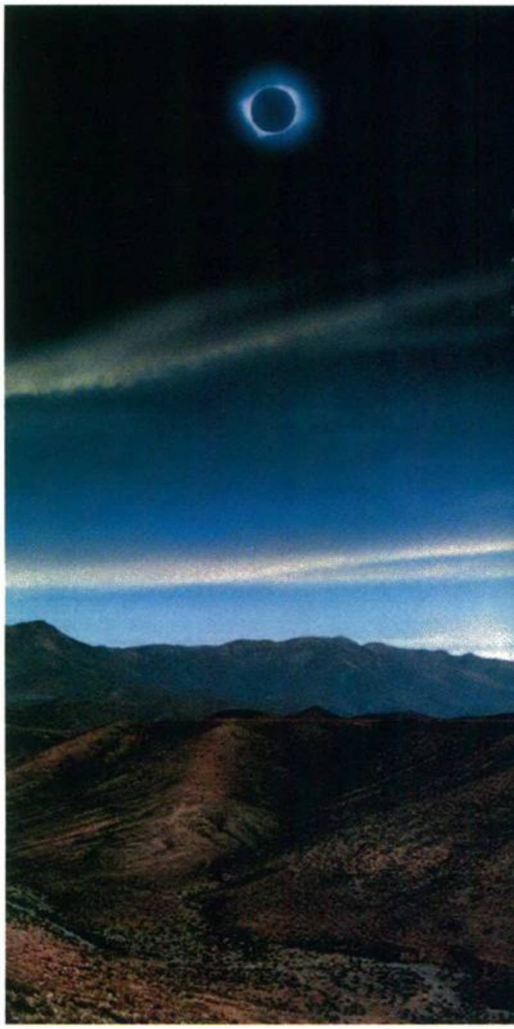
Gathering at the Equinox

▶ Museum of York County, 4621 Mt. Gallant Road, Rock Hill, South Carolina 29732. Sponsored by the Museum of York County and the Carolina Skygazers. For information send a SASE to Barbara Reynolds, Settlemyre Planetarium at the above address; (803) 329-2121; website, http://web.cetlink.net/~btcrook/GATE.htm.

MARCH 21–22

Telescope/Optics Workshop

▶ Math/Science Building, Western Washington University, Bellingham, Washington. Contact Kreig McBride, 402 East Horton Road, Bellingham, WA 98226; (360) 671-1665; e-mail, kmcbride@memes.com; website, http://www.wwu.edu/~skywise.optics.html.



H. Fisk Johnson

The November 3, 1994, South American solar eclipse taken from Putre, Chile. (composite photo)

MARCH 26–29

Peach State Star Gaze

▶ Camp McIntosh, Indian Springs State Park, Jackson, Georgia. Sponsored by the Atlanta Astronomy Club. Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278; (770) 979-9842; e-mail, ken.poshedly@mci2000.com.

APRIL 10–13

National Australian Convention of Amateur Astronomers

▶ Sutherland Entertainment Centre, Sydney, Australia. Hosted by the Sutherland Astronomical Society. Registration deadline, January 31, 1998. Contact the *18th NACAA Secretary*, P.O. Box 31, Sutherland, NSW, Australia 2232; website, http://www.ozemail.com.au/~sasi.

RESOURCES

Planting Primordial Seeds (page 38)

The Whole Shebang, by Timothy Ferris, (Simon & Schuster, 1997). An up-to-date account of modern cosmology.

Blind Watchers of the Sky, by Rocky Kolb, (Helix Books, 1996). A history of astronomy and cosmology.

The Story of Starbirth (page 50)

Cosmic Clouds, by James B. Kaler, (W. H. Freeman, 1997). Eloquently covers star and planet formation.

Through the Eyes of Hubble: The Birth, Life, and Violent Death of Stars, by Robert Naeye, (Kalmbach, 1997). Discusses star birth and the contributions of the Hubble Space Telescope.

Plunge into Darkness (page 74)

Chasing the Shadow: An Observer's Guide to Eclipses, by Joel K. Harris and Richard L. Talcott, (Kalmbach, 1994). Everything an eclipse chaser needs to know to observe a solar eclipse.

PHOTOFACTS

p. 77: Baily's Beads, Fred Espenak, 4-inch f/6 refractor with 2x teleconverter, Kodak Echtachrome Elite 100, 1/125-second exposure, October 24, 1995; Diamond Ring effect, W. L. Reyna, 600mm lens at f/11, 1/250-second exposure, July 11, 1991; **p. 78:** Eclipse composite, Fred Espenak, images were made with a 60mm f/15 refractor. The partial phases were made with a Kodak ND 5.0 filter with Ektachrome 64 film, 1/6-second exposure. Approximately 12 minutes elapsed between exposures. The filter was removed for totality and the sun was exposed for 1 second, March 7, 1970; **p. 79:** Prominences, Roland and Marjorie Christen, 4.1-inch f/6.0 refractor with camera at f/12, Kodak Ektar 125 film, 1/60-second exposure, July 11, 1991; Coronal Streamers, Ralph Malaker, 4-inch f/10 refractor, Kodachrome 64 film, 1-second exposure, June 11, 1983.

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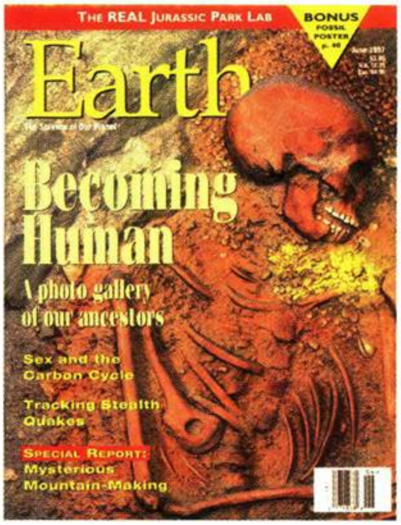
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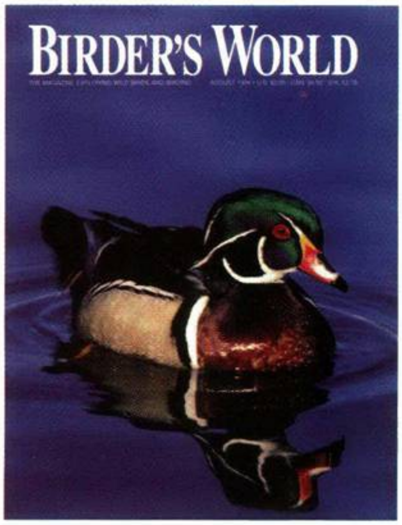

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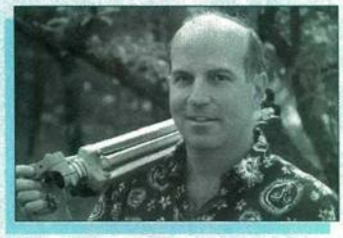

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AULD LANG SYNE

Farewell to an Old Friend

Comet Hale-Bopp graces the skies one last time for a star-studded group of astrophotographers.

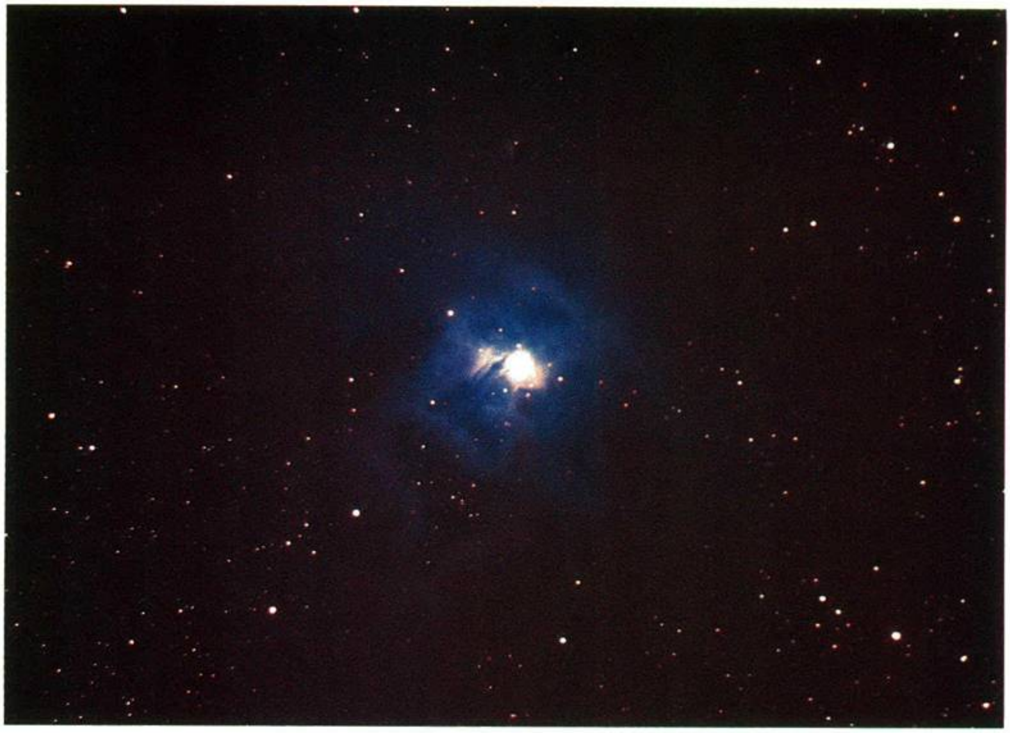
▶ From its discovery in July 1995 until May 1997, Comet Hale-Bopp was tracked closely by small telescope owners. While the average comet comes and goes in a matter of months, this one could be tracked for almost two years. But determined observers wanted even more. They got their wish when Hale-Bopp presented itself to northern viewers for the last time as a distant speck along the southern horizon in the late summer and early autumn of 1997, before becoming a fading object visible only to southern observers. This final appearance extended the period of available viewing to more than two years — a milestone worthy of celebration.

Appropriately, co-discoverer Alan Hale was one of the

Hale-Bopp Fading Fast

CHRIS SCHUR

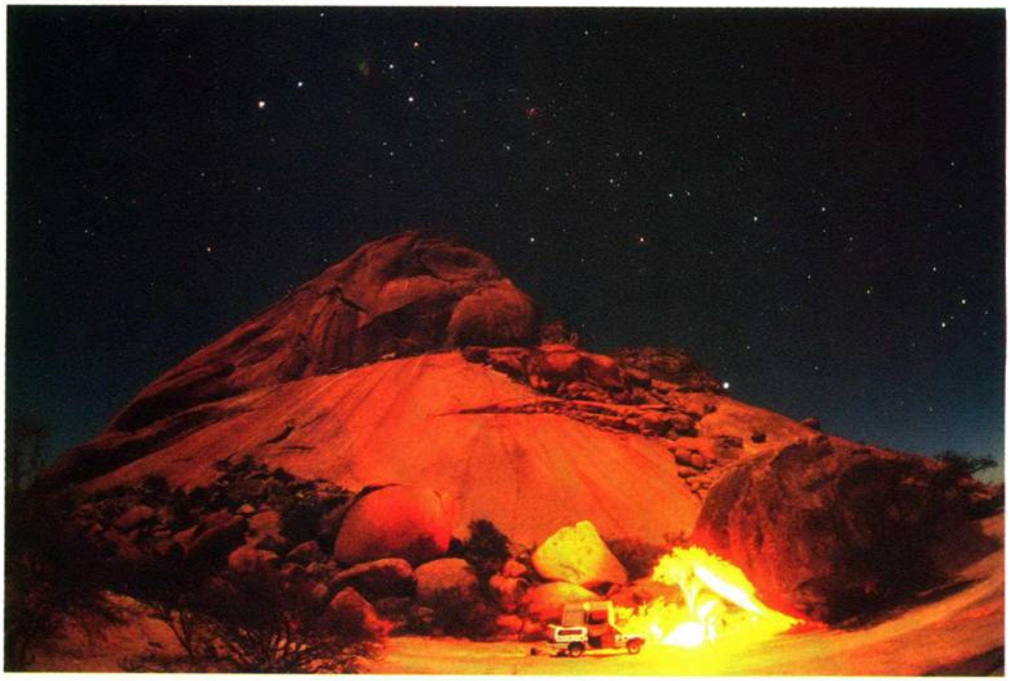
(5.5-inch f/1.65 Schmidt camera, Kodak PPF 400 film, 6-minute exposure taken October 5, 1997)



Reflection Nebula NGC 7023 in Cepheus

GEORGE GREANEY AND DEAN EASTON

(14-inch SCT at f/7, hypered Fuji SHG 400 film, composite of two 60-minute exposures)



The Southern Cross Over Spitzkoppe in Namibia

MICHAEL HOPPE

(16mm lens at f/2.8, Kodak Elite 100 film, 60-second exposure) first in the United States to recover the comet. From Cloudcroft, New Mexico, on the morning of August 31, he could just make out the inner coma of the comet with an 8-inch telescope. Two nights later, using 10x70 binoculars, he noted that it was considerably higher in the sky.

Over the course of the next several weeks, observers in the southern United States devotedly rose before dawn to get a last glimpse of the great comet. Though more than three astronomical units from Earth (three times the distance from Earth to the sun), it was still a captivating sight, exhibiting a ghostly tail and a squashed coma resembling an edge-on galaxy.

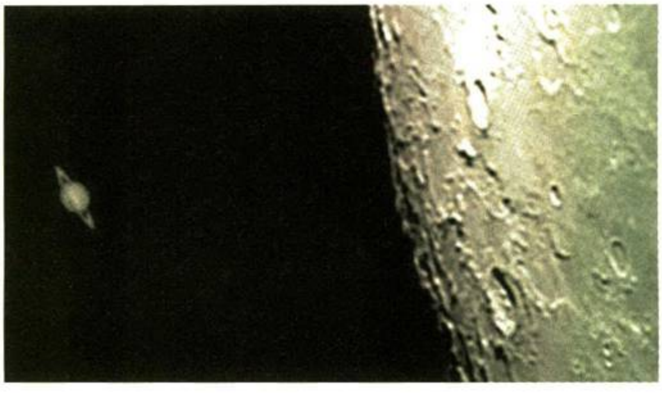
On the morning of October 1, Phil Harrington made one of the northernmost observations of the reappearing comet, from a site nearly 40° north latitude. He set up at a beach on the south shore of Long Island and waited for the comet to rise. Using 11x80 binoculars, he saw Hale-Bopp as a dim, diffuse glow just northwest of a 6th-magnitude star. As Phil put it, it was "nice to see an old friend one more time."

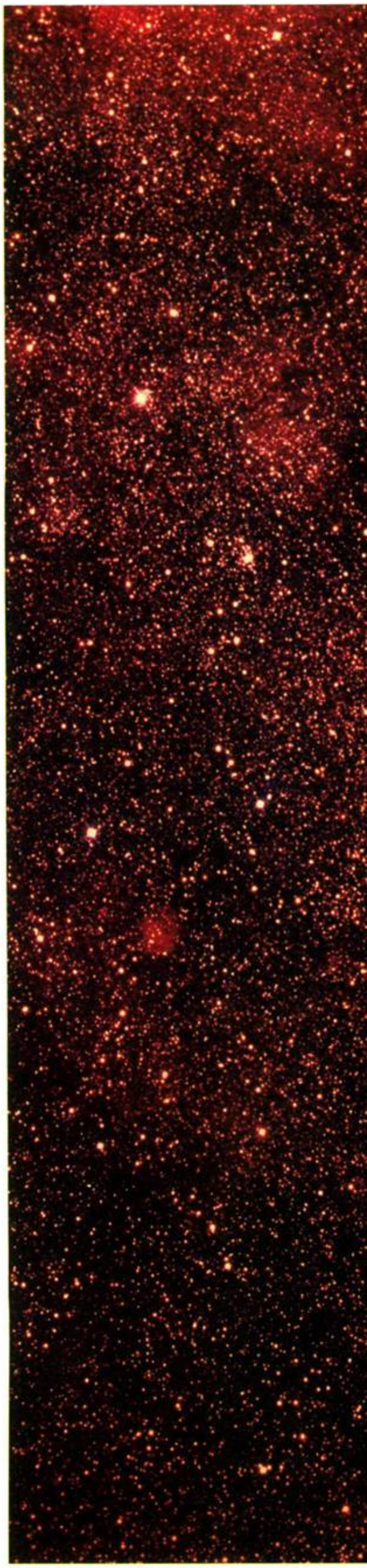
A couple of hours after his flight from Philadelphia to Phoenix landed, astrophotographer Jerry Lodriguss joined me at my observing site, 50 miles south of Phoenix. When not capturing the night sky on film, Lodriguss is a sports photographer for the *Philadelphia Inquirer* — and he's more than happy to accept an assignment in Phoenix when it coincides with a new moon. We moved my 20-inch scope from one object to another until the glow of morning twilight was only minutes away. I handed Jerry my little 7x20 binoculars and instructed him to

Cassini Launches!

PETER GUALTIERI

(20mm lens, Fuji 100 film, 5-minute exposure taken October 15, 1997; exposure began at f/22 and ended at f/2.8 as the scene dimmed)





The Moon Occults Saturn

GREGORY TERRANCE

(10-inch f/6 refractor at f/30, ST-7 CCD camera, 11-second exposure taken November 11, 1997)

NGC 6888, B145, Sharpless 2-101, NGC 6871, and Sharpless 2-104 in Cygnus (clockwise from top).

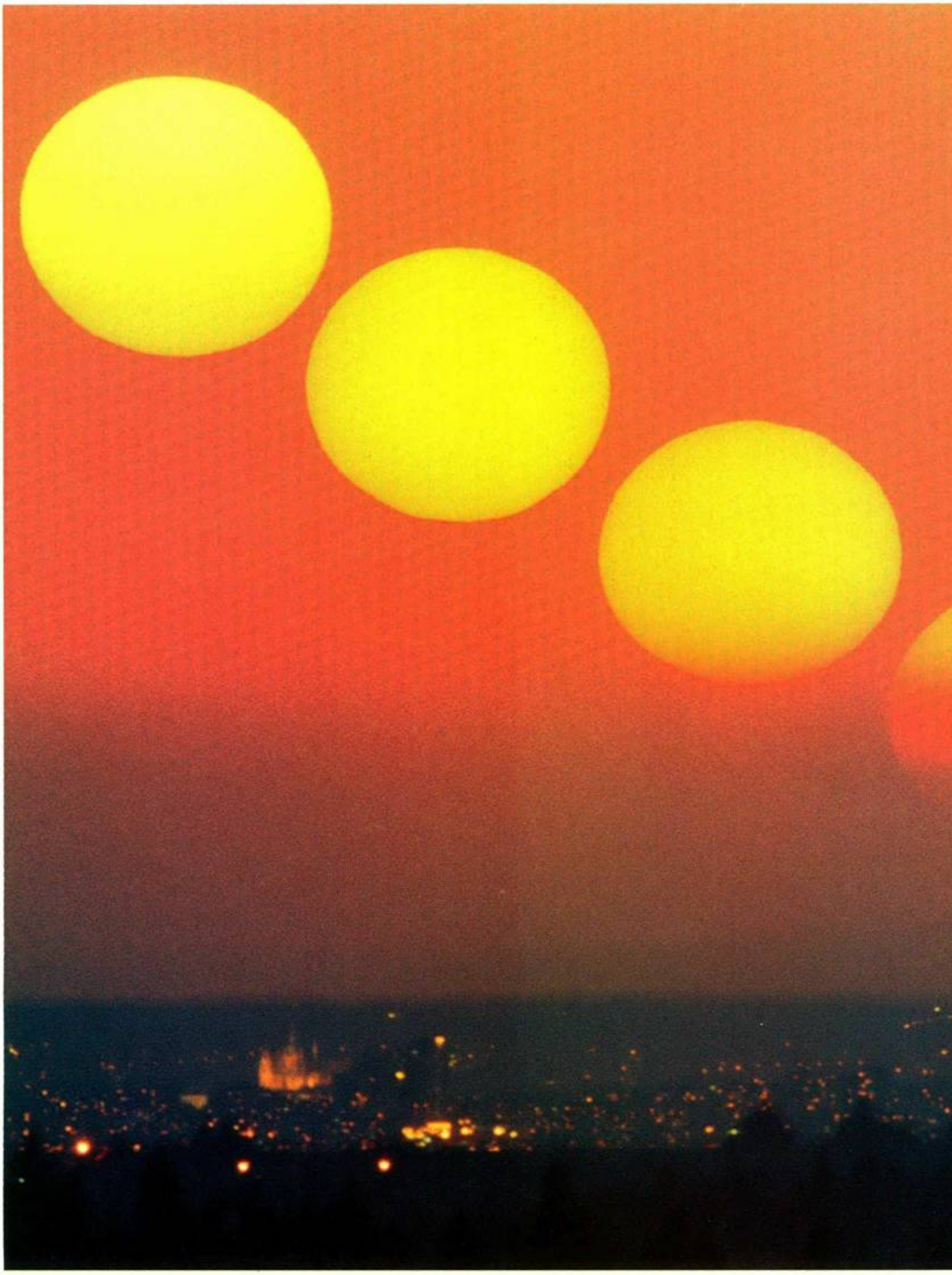
JASON WARE

(12-inch f/2.2 Schmidt camera, Fuji HG 400 film, composite of two 7-minute exposures) point them just below a fairly bright star along the southern horizon. "See that fuzzball?" I asked. He expected me to rattle off some NGC designation and was floored when I told him instead that this was the comet he thought he would never see again.

Arizona's string of clear nights continued through to the next night, and a group of Phoenix observers set up in the low desert near Sentinel, a hundred miles from the city lights. Chris Schur brought a 16-inch telescope and a long list of faint comets, none of which was brighter than magnitude 12.5. Those who set up near Chris were treated to such obscure gems as Comet Gehrels 2 and Comet Kowal 2. Observations of these comets usually left people wondering whether the objects were centered properly. Chris's seventh find of the evening, however, was Hale-Bopp. He was barely able to glimpse it with his unaided eyes, but through his scope it displayed a bright coma, elongated at nearly a right angle to a broad fan tail, which extended nearly a degree and a half.

In the years since 1993, we have seen one comet collide with a planet, witnessed another miss us by a mere ten million miles, and now watched a third hang around for more than two years. The 1990s have certainly been a great decade for comets — and they're not over yet.

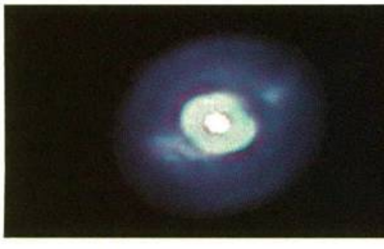
Tom Polakis is a deep-sky observer and photographer living in Tempe, Arizona. His article "Stargazing at Kitt Peak" appeared in the July 1997 issue of Astronomy. *Check out his website at http://www.psiaz.com/ polakis/skyphoto.html.*

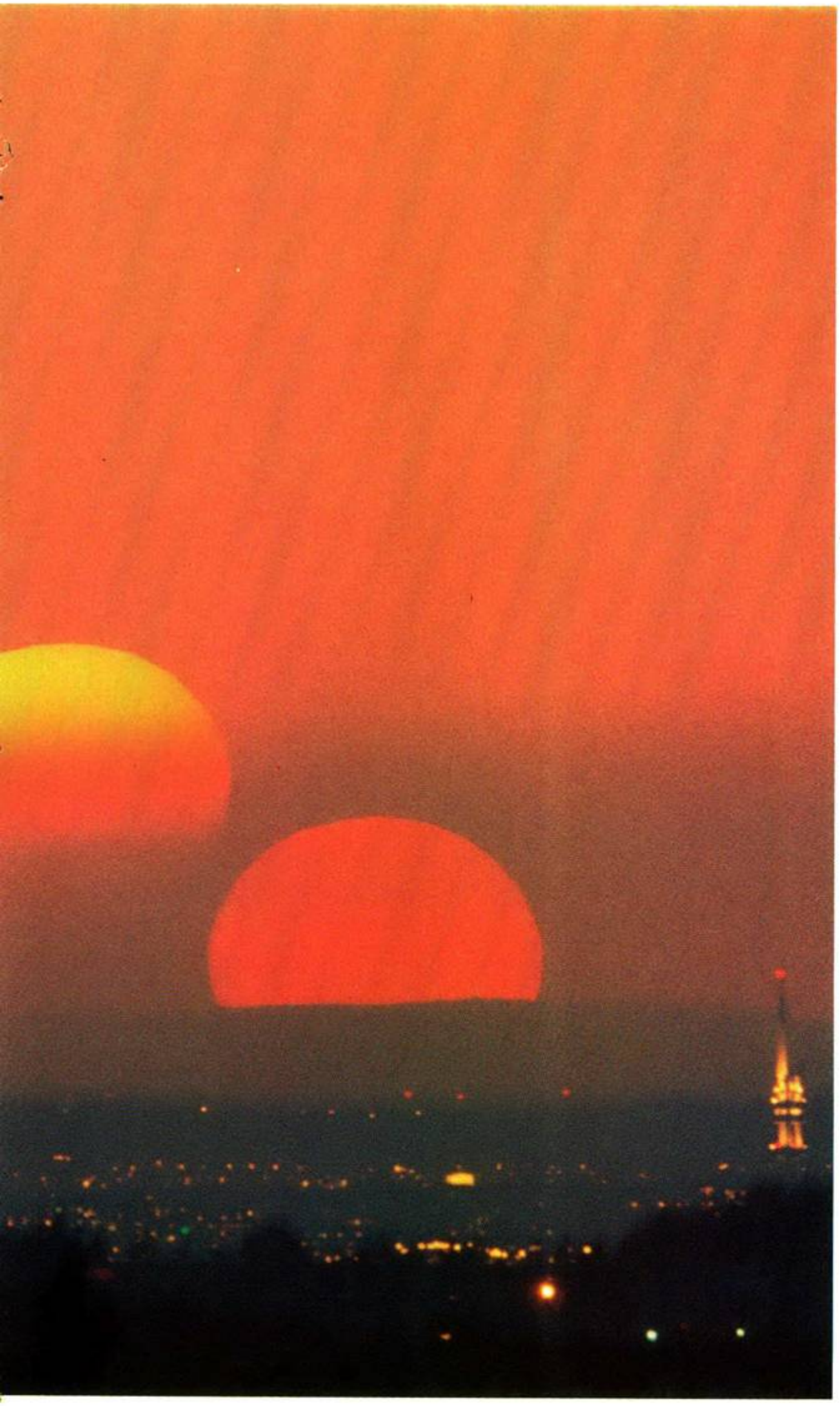


Sunset Above Prague Castle

ALES KOLAR

(500mm lens at f/6.3, Konica VX 200 film, composite of four 1/8000-second exposures and one 1/1000-second exposure; foreground was a 22-second exposure taken June 6, 1997, from Ondrêjov, Czechoslovakia)





The Blinking Planetary (NGC 6826) in Cygnus

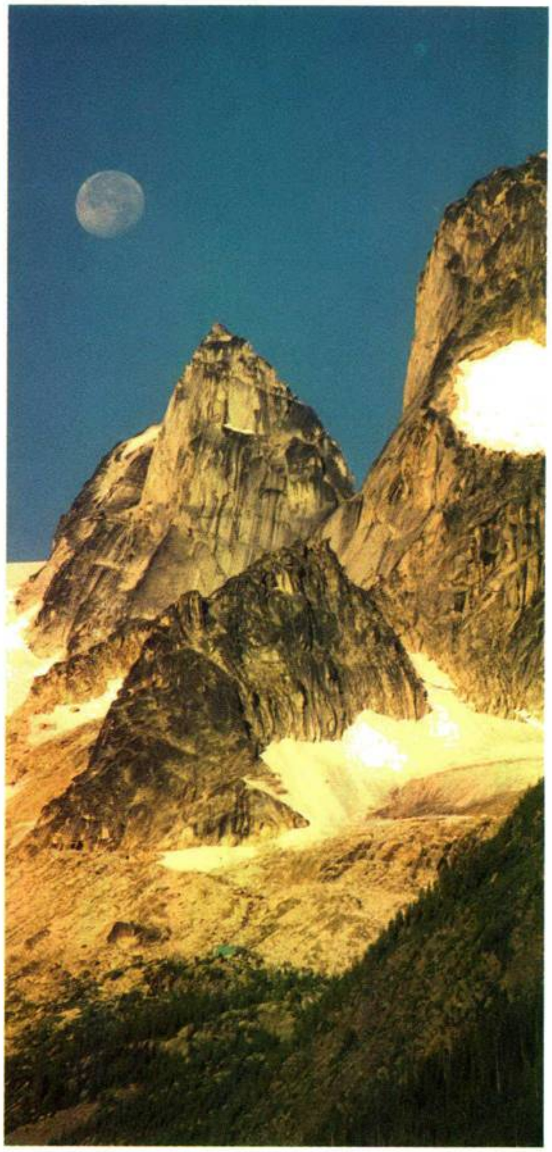
JACK NEWTON

(16-inch f/10 SCT, Pictor 1616XT CCD camera, composite of 60-second red and 3-minute green and blue exposures)

The Dumbbell Nebula (M27) in Vulpecula

TIM PUCKETT

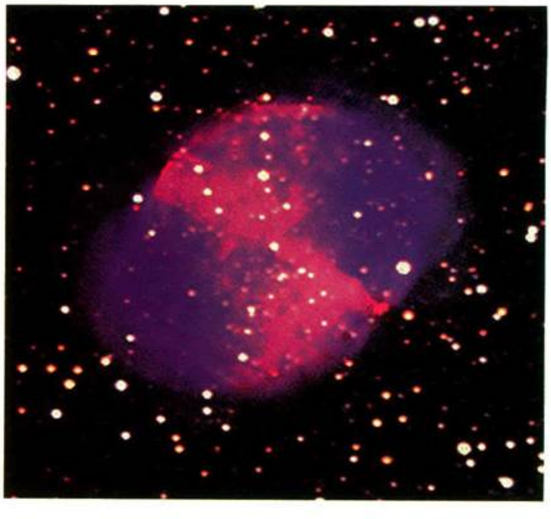
(12-inch f/6.2 SCT, Apogee AP7 CCD camera, composite of three 5-minute exposures through red, green, and blue filters)



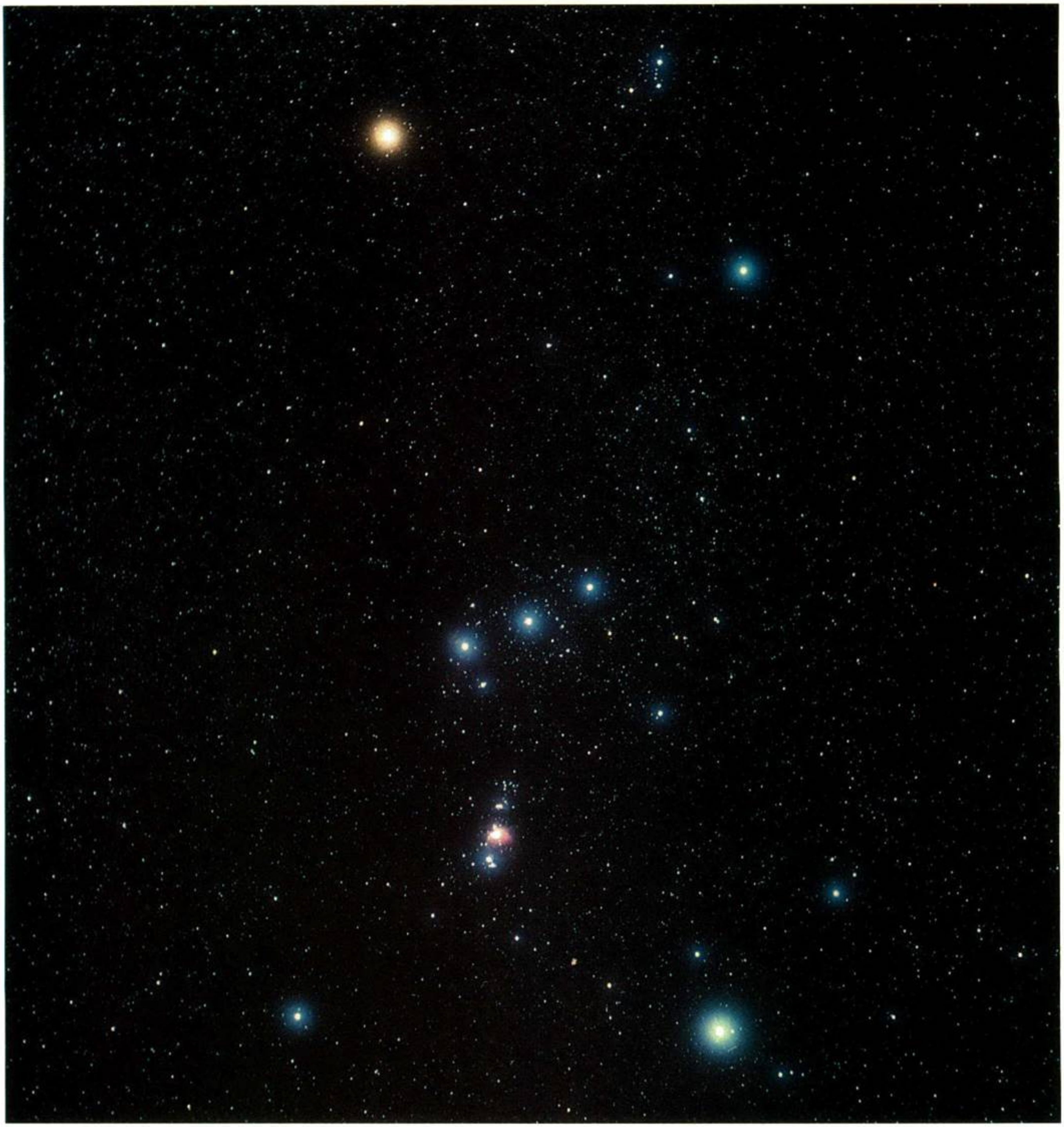
Moon Over the Bugaboos

MANFRED EFFENHAUSER

(200mm lens at f/11, Kodak Gold 200 film, 1/250-second exposure taken on August 19, 1997)



This month's best astrophoto



The Great Hunter

JOHN CHUMACK

(80mm lens at f/4, medium format camera, Kodak PPF 400 film, 30-minute exposure)

The constellation Orion heralds the winter skies. Who can gaze at this stellar monument and not linger outdoors awhile longer despite the frigid temperatures? For dedicated observers, Orion holds some of winter's most spectacular celestial treasures.

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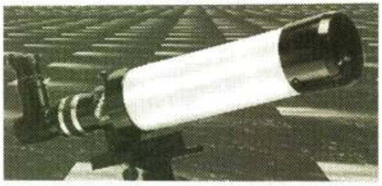

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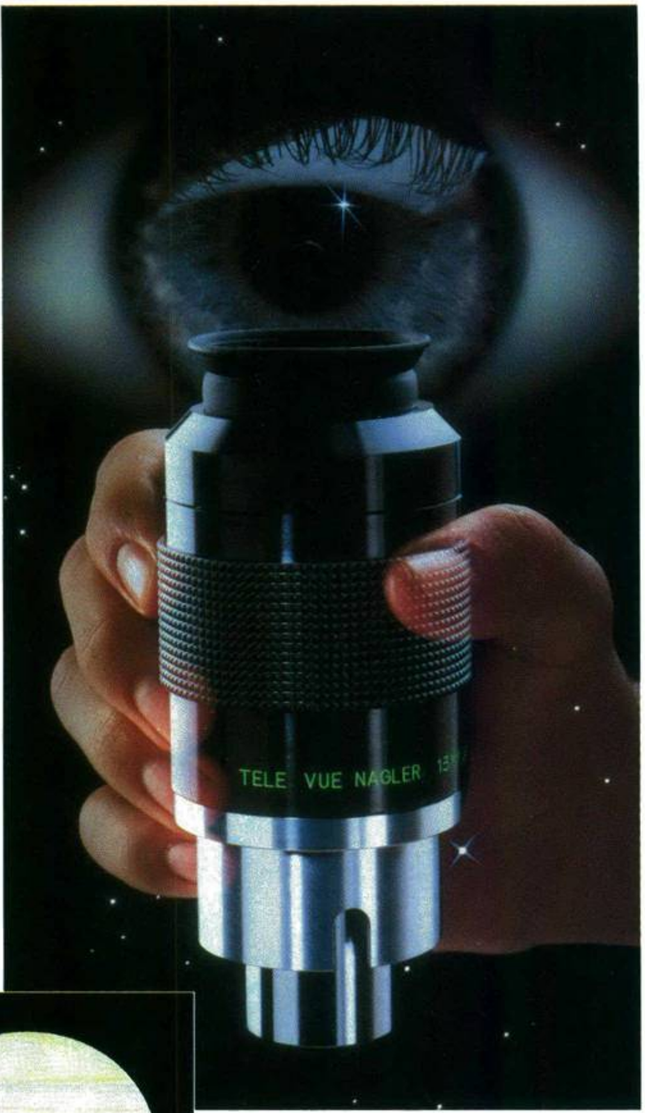
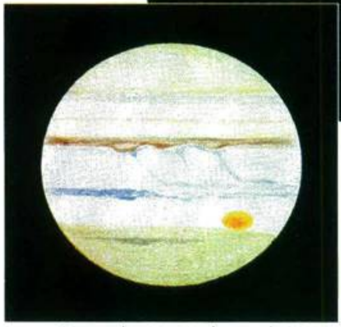
Dear Mr. Nagler,

"I thought it long overdue that I write to give my impressions of your Nagler eyepiece designs. *I say 'long overdue,' because I bought my first Nagler (a 7mm) back in 1984. The reason for the purchase was that earlier that year I had invested in a Celestron C-11 and a 4" Fluorite, F/9 refractor. I thought that the stated objectives of the Nagler design — long eye-relief and a wide, highly corrected field of view, would exploit the full potential of a telescope with 2,800mm focal length, and the imaging capacities of a fine refractor. I was not disappointed. Soon after came the fantastic 9mm and 11mm Naglers and then the 4.8mm for the refractor.*

These eyepieces have given me my most rewarding hours spent at the telescope. *My main interest is in the planets which I draw and give lectures on at our local school and observatory. The observation of the planets requires painstaking hours spent at the eyepiece. The Naglers suit my purposes exactly.*





Drawn by Mr. Toohey with 12 N2

When the Type 2s were introduced onto the market I could not resist them. I purchased the 16mm and 12mm models. The 20mm seemed too large, heavy and costly, so I left it alone. These were the same reasons for not buying the 13mm (apart from the fact that by then I owned a 12mm Type 2). However, earlier this year, after years of looking through other people's 13mm and 20mm Naglers, I finally decided to take the plunge myself. ***So now I own a full set of Naglers*** *(including the wonderful 11mm which despite many offers, I will not part with).*

When I remember what eyepieces for the amateur market were like before the introduction of the Naglers (like looking down a drain pipe, or 60° fields, with astigmatism and severe edge of field aberrations), ***it is clear that your designs have taken us a quantum leap forward. No other eyepieces, in the Naglers' range of focal lengths, satisfy me now.***

Many of my fellow planetary observers say that conventional field eyepieces are sufficient. In a way they are right; good Plössls, for example, produce superb images. However, I believe the extra eye-relief, the huge field of the Naglers, coupled with marvellous image correction and the impression that ***the telescope simply gets out of the way,*** *all add up to a delightful psychological difference when using the Naglers. One feels more involved, more present to what one is viewing.*

Over the years I have found that amateur astronomers can be fairly stubbourn people in somehow defending their choice of equipment. Next thing you know they upgrade what was once, in their view, the very best available. ***Only good products stand the test of time. For me, the Naglers are such a product.*** *Not only have they remained with me; I have kept buying more of them!*

To some extent, astronomy, and particularly amateur astronomy, is about emotion and the involvement of the imagination. ***I have to say that Nagler eyepieces have captured my imagination.*** *As well as giving pride of ownership, Naglers are immensely satisfying and a joy to use.*

The little instruction sheet that comes with the eyepieces says that you wish the user 'years of exciting viewing with these eyepieces, and welcome comments on your experiences with them.' So you asked for it. After a decade of superb images (many of which remain etched on my memory; most of which I have recorded on paper) I felt it timely to share my comments and to thank you for your contribution to amateur astronomy."

Yours Sincerely.
Christopher A Toohey

Christopher Toohey, Australia

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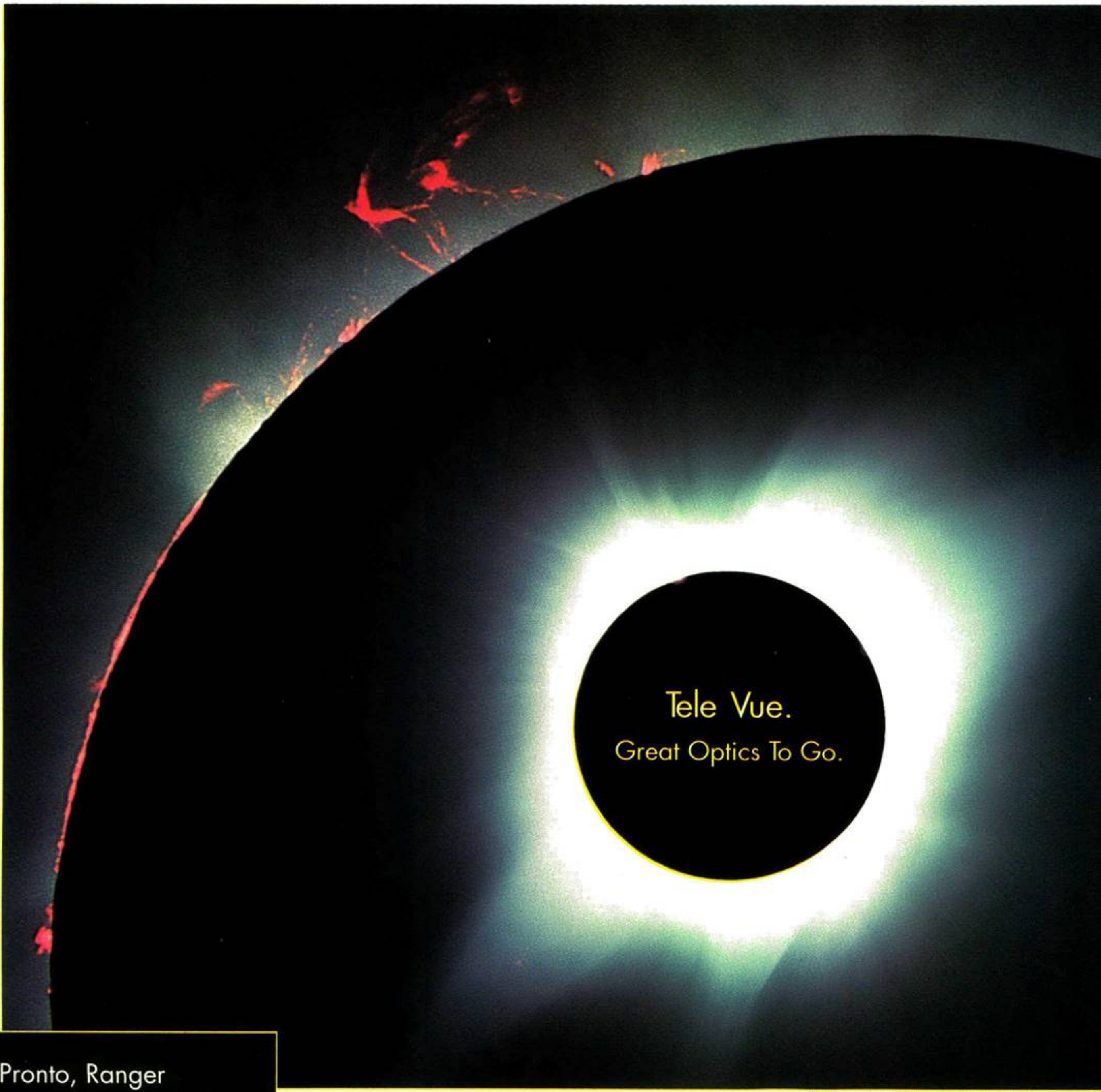

Genesis solar photography by Joe Folmer.

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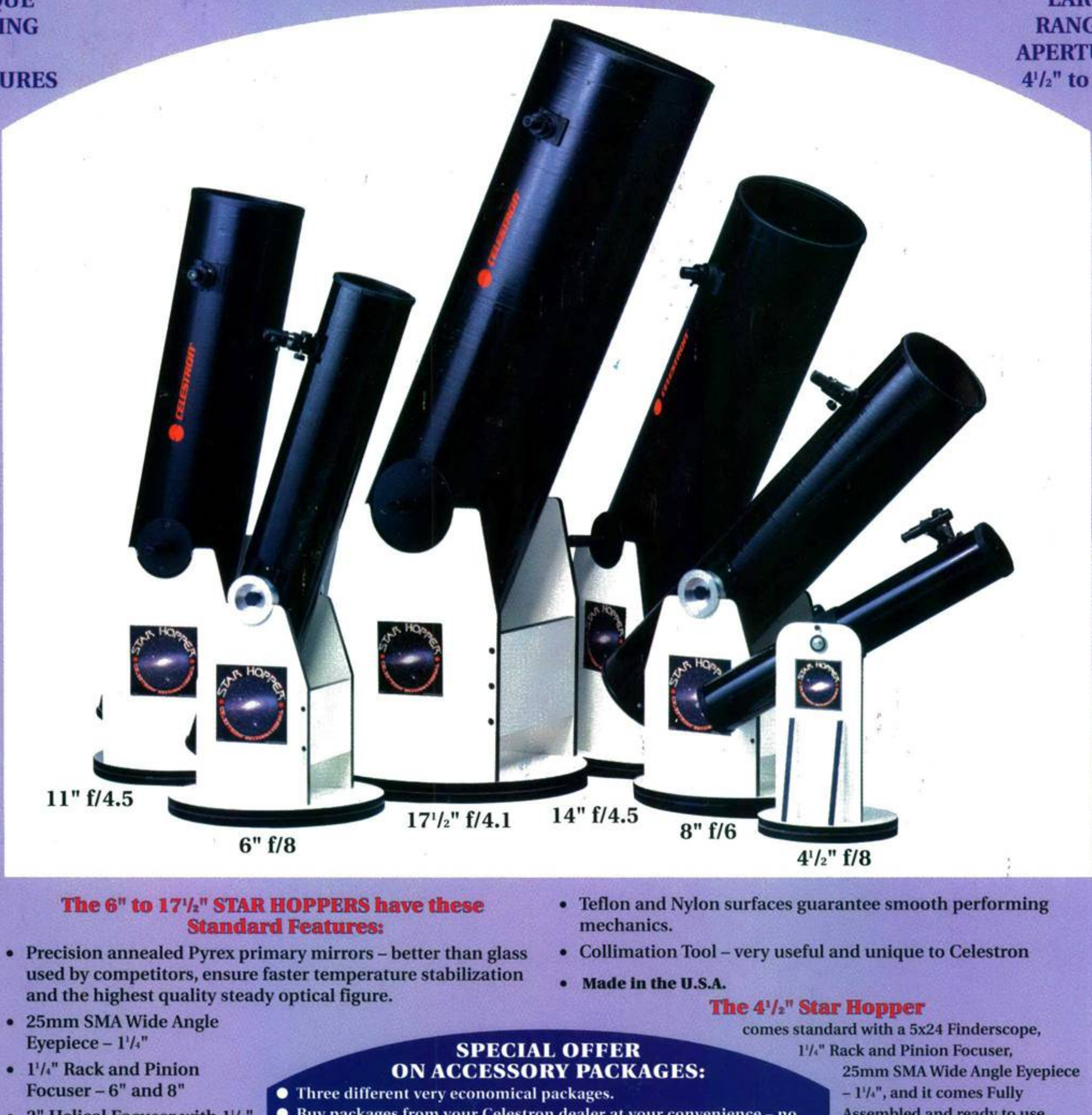

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